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ELECTRIC LIGHTING FOR THE BALTIMORE TUNnel of the Baltimore & Potomac Division of the Pennsylvania R. R. is to be installed shortly, and a contract for the work has been let to David E. Evans & Co., of Baltimore, Md. There is a traffic of about 250 trains per day through this tunnel, and the track maintenance in the darkness and smoke is dangerous and expensive.

AN INTERLOCKING MACHINE which is soon to be installed at the junction of the New York, New Haven & Hartford R. R. and New England R. R., at Hartford, Conn., has 64 levers, of which 58 are working levers (28 for signals, 13 for switches, 15 for facing point locks and 2 for movable frog points), and 6 are spare levers. The locking frames are vertical, and the rocker link slots carry rolling instead of sliding blocks, which lessens the force required to throw the lever. The preliminary locking is effected from the latch handle. The slide bars, locking dogs, pins and other working parts are of cold rolled steel, while the links, lever socket, bell cranks and other fittings are malleable iron castings. The wearing surfaces of the slots in the frame for the locking dogs and of the sector guides for the levers are milled in special machine tools. This interlocking machine was made by the National Switch & Signal Co., of Easton, Pa.

COMPETITIVE PLANS FOR THE JUNGFRAU RAILway are invited by the Preliminary Scientific Association for the Construction of the Jungfrau Ry., which offers prizes amounting to $6,000 (30,000 francs). The general plan of construction, details of track and structures, estimates of cost, methods of tunneling, power transmission, electric lighting and heating of the tunnel, stations and cars are all to be included. The Jungfrau Railway Co. claims the right of utilizing the plans receiving prizes without further compensation, all other papers will be returned to their authors. The maximum grade is to be 25%; gage of track, 1 meter; minimum radius of horizontal and vertical curves, 328 ft. and 1,640 ft.; cars, 8.2 ft. wide and 9.84 ft. high; speed, 4½ to 6¼ miles per hour. The water power for the electric plant, about 5,000 HP., will be taken from the Lutschine River, and the distance from the turbines will be 4.36 miles to the commencement of the line and 1.55 miles thence to the tunnel, which will be 6.2 miles long. Further particulars can be obtained from Mr. Guyer-Zeller, President, Jungfrau Railway, Bahnhoffstrasse 10, Zurich, Switzerland. All plans offered in competition must be deposited by Aug. 1, 1896.

A CONCRETE ARCH on the Melan steel and concrete system is to be built at Paterson, N. J., over the Passaic River. The bridge will be a three-span structure with a total length of 295 ft. and a width of 54 ft. Detailed plans and specifications are being prepared by the Melan Arch Construction Co., of 71 Broadway, New York city, and bids have been called for, as announced on another page of this issue.

THE SOUTH HALSTED STREET LIFT BRIDGE, at Chicago, Ill., was injured by the fall of several castings of one of the counterweights on April 1. This bridge was described in Engineering News April 19, 1894. Briefly stated it consists of a 138-ft. trussed span moving vertically between two towers and counterbalanced by means of a series of cast-iron weights which slide up and down in vertical guides attached to the towers. There are four of these counterweights, one attached to each corner of the span, by means of a wire rope passing over a sheave at the top of the tower. When near the top of the tower several of the 10 × 12 ins. × 8 ft. 7 ins. cast-iron blocks forming one counterweight fell and broke through the floor of the approach span. Some of the minor tower and floor members were injured but the chief damage resulted from the delay to traffic on the river. The fall of the counterweight blocks was caused by a breaking-pin which exhibited a very bad flaw of apparently long standing, indicating that the inspection had not been careful. An investigation instituted by City Engineer Jackson showed that the design of the broken pin was good and that the failure was due to faulty material as noted above. Mr. Jackson informs us that the accident was due to no fault of the design and indicates nothing but that faulty material had been passed by the inspector. We have also been informed by the Pittsburg Bridge Co., the contractors for the bridge, that they did not furnish the material which failed.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was the failure of a trestle on the Bedford Belt R. R., at Bedford, Ind., April 13. The structure gave way under an engine, and the engine and a flat car went down. Five men were killed and two injured.——A combination of derailment and collision occurred on the Erie R. R., at Sparrowbush, N. Y., April 11. A car of an eastbound freight train left the rails and fouled the westbound track right in front of a fast freight train. The engine of this train went down the bank and the fireman was seriously hurt.——A bridge failure occurred on the Wheeling & Lake Erie R. R. at Toledo, O., April 8, in which one man was killed. A heavy steam shovel was being pushed over the Maumee River bridge by a locomotive when it jumped the track and ran into the truss, causing the wreck of the 80-ft. span.——A small trestle on the New Orleans & Northwestern Ry., near Vosburg, Miss., gave way under a passenger train April 14 and all the cars went down. Ten persons were injured but nobody was killed.

AN EXPLOSION OF DYNAMITE at the west end of the new tunnel at Radebaugh, Pa., on the realinement of a part of the Pennsylvania R. R., occurred April 7, killing one man and injuring two others. The men were thawing dynamite at a stove.——An explosion of giant powder in a premature blast at a quarry near Ogden, Utah, on April 8, killed seven men and injured three others.

AN EXPLOSION OF A MAGAZINE took place in the 1,100-ft. level of the St. Lawrence mine, near Butte, Mont., on April 11. Two men were killed by the force of the explosion and four others by foul air resulting from it.

BIDS FOR GARBAGE DISPOSAL IN NEW YORK will soon be asked again, making the fourth call within six months, all the bids opened on March 30 for garbage disposal alone, and for the disposal of this and other city wastes, having been rejected. Col. Geo. E. Waring, Jr., M. Inst. C. E., Commissioner of Street Cleaning, advised that the contract be awarded to the Merz Universal Extractor & Construction Co., of New York, at their bid of $144,000, but the Board of Estimate and Apportionment refused to do this. Col. Waring reported that the processes proposed by Kelly & McGlehan and A. O. Bradley were still in their experimental stages and that Mr. Z. F. Magill failed to file the required plans and specifications. Besides this, Kelly & McGlehan proposed to use the residue after cremation for filling bulkheads, which Col. Waring states is contrary to the specifications. The processes proposed by the Merz Co., The New York Sanitary Utilization Co. and Mr. Emil Holthaus, Col. Waring considered as satisfactory and therefore recommended awarding the contracts to the Merz Co., the lowest of these three bidders. The Board of Estimate and Apportionment decided to amend the specifications, it is stated, so that the contractor will have the privilege of "trimming the dumps," or, in other words, sorting out salable material from the garbage and refuse as it is dumped from the carts. This was prohibited by the specifications. The new bids, it is reported, will be for garbage disposal alone, the disposal of other refuse, only, and the disposal of garbage and all other refuse. The bids under the last call were published in our issue of April 2.

BIDS FOR STREET CLEANING and the removal of ashes and rubbish in Brooklyn will again be received by Mr. Theo. B. Willis, Commissioner of Public Works, this time on April 21. The bid received on March 10 and published together with an abstract of the specifications, in our Construction News Supplement for March 12 have been rejected. The contract will run for three years.

A CONTRACT FOR AN INTERCEPTING SEWER AT Hartford, Conn., to keep sewage out of Park River has been awarded to P. H. Harrison & Sons, Newark, N. J., for $213,802, which was $28,614 lower than the next highest bidder. The bids for this work are published in our Construction News Supplement this week.

BIDS FOR SIX SECTIONS OF THE NASHUA AQUEduct will be received until April 30 by the Metropolitan Water Board, 3 Mount Vernon St., Boston, Mass. Bidders may submit proposals for any one of the sections or for the work in halves. Mr. F. P. Stearns, M. Am. Soc. C. E., is Chief Engineer.

THE NICARAGUA CANAL COMMISSION'S REPORT is reviewed by Mr. A. G. Menocal, Civil Engineer U. S. N., and Chief Engineer of the Nicaragua Canal Company, in a communication to the House Commerce Committee. Mr. Menocal was with the commission in Nicaragua, and he contends that the numerous changes of plans proposed result from a hasty trip through the country and imperfect knowledge regarding the physical conditions and character of the work previously performed. He admitted that the hydraulic and geological data collected by the Canal Company were insufficient, but said that to obtain such full information in Nicaragua would require years of investigation. He combats at length the proposed change at the Greytown entrance, as being unnecessarily costly, as being more exposed than the older plans and as being unacceptable to the Nicaraguan government. Mr. Menocal still adhered to his plans for the Ochoa dam and said that the commission did not personally investigate the site of the dam, though he had prepared a camp for a six days' stay. He firmly believed that the canal could be built and put into operation for $65,000,000. Col. James Andrews, of Pittsburgh, opposed the building of the canal, before the same committee, in the interest of the Tehauntepec ship-railway.

THE DUDLEY-POWER-PNEUMATIC GUN was tested on April 13 before Gen. Nelson A. Miles and other officers of the army and navy, but after successfully throwing five 32-lb. projectiles charged with 15 lbs. of explosive gelatine, the gun was wrecked by the premature explosion of a shot charged with black powder, and one man was injured seriously. This gun is made up of a long central tube and two parallel shorter ones connected by collars and circulating ports. The power is compressed air generated, not by pumps, but by the explosion of a powder charge in one of the side tubes. The resulting pressure, which is regulated by the amount of powder burned, is conveyed down the opposite smaller tube and to the rear of the projectile in the center tube, and this pressure was 850 lbs. per sq. in. in the experiment made. Three high explosive projectiles were discharged successfully and accurately and two failed to explode after being fired, at a range of about 2,100 yds. The dummies contained 4 lbs. of powder and were to be used in target practice. The exact cause of the explosion is not known, but the wooden plug, forming part of the dummy, was found split and wedged in the central tube, which was the one that burst. Mr. H. P. Ewell, the Consulting Engineer of the company, said that the gun had demonstrated its ability to safely and accurately discharge high explosives, and the failure came from a cause that would wreck any gun.

THE U. S. RAM "KATAHDIN" had an official trial, on April 9, over the 36-knot course in Long Island Sound. She did not develop a greater speed than 14¼ knots per hour, and her average was below that. To develop the highest speed required forced draft, 155 lbs. of steam pressure and 130 revolutions of the screws per minute. At this speed the water boarded the forward part of the ram in great quantities. But as regards her tactical diameter and general handling, the report is said to be favorable.

GRAPPLE DREDGES FOR CANAL WORK have been built by Cockburn & Montgomery and H. A. Phillips, of London, England, and are used for clearing the Leeds & Liverpool and Grand Junction canals. Each dredge has a bucket of 15 cu. ft. capacity attached to a vertical frame pivoted at the ends of a nearly horizontal frame composed of two arms extending back on either side of the engine house, where they are pivoted to swing in a vertical plane. The outer or free end of this frame is suspended by tackle from a crane jib or boom, by means of which it is raised or lowered. The whole apparatus revolves with the turntable on which the engine is mounted, and the grapple or bucket is opened and closed by the piston-rod of a vertical steam cylinder bolted to the vertical frame. The apparatus can be folded down so as to allow the dredge to pass under canal bridges of 10 ft. headway. The scows are of 25 tons capacity, and are hauled away by a steam tug to a discharging plant similar to the dredging plant, but mounted on a car running on a track along the canal bank. This plant raises 2½ tons at a load and discharges 60 tons per hour.

THE RESERVOIR CONTRACT SUIT of Frescoln & Rooney vs. the city of Lancaster, Pa., was settled last week by the payment of $13,500 to the contractors whose suit was for $7,000 balance due and $33,000 for extras. The suit arose over the failure, on Oct. 14, 1894, of the reservoir built by the contractors for the city, soon after its completion.

THROWING DOWN A CHIMNEY AT LAWRENCE, MASS.

In the construction of a new mill building, at Lawrence, Mass., recently, it became necessary to remove a chimney 110 ft. in height. It was decided to throw the chimney down, and to do this the brickwork was cut away at the base on the side toward which it was desired the chimney should fall. On the other side was placed a heavy timber brace with its foot resting on a jack screw. When the other side had been cut away as much as was deemed safe, the jack screw was operated until the chimney fell. The work was carried out by Messrs. Peabody & Pike, the contractors for the new mill building, and was entirely successful, the chimney falling within a few inches of the place aimed at, and breaking up completely in its fall. We are indebted to the courtesy of Mr. Ivar L. Sjostrom, C. E., of Lawrence, Mass., for the photographs from which the accompanying illustrations are reproduced, and for the information given above.

View of Chimney Before Fall.

A "Snap Shot" as the Chimney Fell.

THROWING DOWN A BRICK CHIMNEY AT EMMAN'S MILL, LAWRENCE, MASS.; APRIL 1, 1896.
Peabody & Pike, Contractors.

THE ART OF FIREPROOFING.

By Herman B. Seeley.

II.

(Concluded from p. 237.)

Protective Coverings.—Before taking up this branch of the subject it will be well to understand its economic relations. In the first place, the incombustible frame is worth its increased cost because of its stability, in all buildings except those devoted to manufacturing solely and devoid of finish. The combustible frame is so subject to shrinkage and deflection of timbers that it is impossible to maintain by repair its original standard for more than a comparatively limited term of years. By reason of the many openings for pipes in modern buildings and the degree of supervision necessary to guard all points, it is practically impossible in most buildings to fireproof a combustible frame so as to prevent its ignition by fire. Once such a fire gets under headway, the very means employed to protect the frame prevent the extinguishment of the fire.

It is plain that any compulsory outlay for the construction and protection of the incombustible frame beyond the plain requirements of each individual case is an economic error, as it tends to raise the cost to a prohibitive point and promotes an absolute waste. All of the fireproof constructions on the market are installed according to methods found to provide for their erection on the lowest basis of cost. Fire records show that these methods suffice for numerous classes of buildings.

In proposing to improve these methods for mercantile buildings, the following rules should be observed: When sprinklers can be used, the cost of the improvement should be less than the cost of sprinklers, and the cheapest form of a protected incombustible construction with the addition of sprinklers will always be preferable to the construction alone, however improved in risks of large areas, or risks whose commercial demands have brought about the connection of floors by stairways. It is not advisable to prepare for the fire that occurs with extreme rarity, assuming a failure of the fire department, because the cost of repairing the damage of frequent moderate fires is thereby increased to a sum in excess of the possible damage, due to one total loss, that might not occur in a hundred years, if ever.

Methods of improvement must necessarily be simple and inexpensive. The imbedding of a wire mesh in the plastering of tile and concrete constructions will insure the retention of the plaster, thereby increasing the thickness of the protection and preventing disintegration from shock of heat and water.

The constructions with ceilings can be improved by back plastering or the deposit of a layer of mineral wool on top of the wire mesh. Since thickness of material is an important factor, only the open metallic meshes should be used as a base for ceilings. The sheet metal laths are advertised to require less plaster than the open-mesh varieties. This should condemn them even if the statement that they buckle and throw off plaster in a fire is unfounded on fact.

Vertical Coverings.—In the first portion of the article the need of using common brick on outer walls was noted. It is evident that a thickness of 4 ins. will suffice, since many columns pass through hot fires unprotected and yet uninjured. A column may be heated up to its maximum loss of strength without expanding to an extent sufficient to cause damage. Any covering with an air space next to the column which will outlast a fire and prevent the access of cold water to one side of a column will suffice.

Wire cloth and plaster is the best device for this purpose. The addition of a clay or plaster of paris tile inside the wire may be made at moderate expense, but in my opinion it is unnecessary. Vertical surfaces, except in rare cases, receive no heat under pressure as do the horizontal ceiling surfaces. The transmission of heat horizontally through a vertical surface is a slow process, which may be easily rendered innocuous by ventilation. In protecting vertical framing members the important point is that the covering shall stay in place until the fire is extinguished.

Ceilings.—The transmission of heat by ceilings, however, is very considerable. The comparative properties of materials and thicknesses and the properties of construction in storing or removing transmitted heat are little understood and reliable data can be had only by careful experiments. The disposition of the heat by the construction is as important a point as the amount transmitted by the ceiling. A stove top over a hot fire remains at a compartively low temperature so long as it passes absorbed heat freely into the air. If mineral wool, however, be placed on the top the heat is retained and acts upon the metal, raising it to a red heat very quickly.

The constructions with connected air spaces are the best, because the intense heat in fires are developed at centers of rapid combustion and not over entire areas. The entire area of air space in such a construction must be heated by transmission at these points before appreciable absorption by the construction can begin. If the construction be such that the column air spaces connect with the floors, the condition of the uncovered stove top may be practically duplicated.

Fireproofing Tests.—Since the great London fire, at regular intervals and with great expense, experiments on fireproofing devices have been undertaken, often with impartial supervision. No real benefits have been obtained from these efforts for several reasons:

(1) The constructions only have been tested and not the protection to the beams that carry them. Note the oft-quoted Denver series, with the beams carried by brick walls safely out of reach of heat.

(2) The effects of actual fires have not been produced. If any tests have illustrated the destruction of tile, as shown in the photographs of actual fires, they are unknown to me.

(3) The temperature attained by the constructions and their expansion have been neglected, and the areas exposed have been too small to show disruptive expansion effects.

(4) The constructions were installed by their promoters, and consequently represented a degree of care and precaution impossible in ordinary use.

Another feature of these tests upon which great stress is laid without much reason is the loading with weights and dropping of weights upon the upper surface of the floors. In a real fire the floor loads are the fuel. Combustion of this fuel on a floor removes the load. If the combustion has damaged the ceiling above so as to affect the floor above, or if the construction is such that the ceiling damage necessitates the removal of the floor the construction is unscientific and a failure. The limit of safety for a floor is established by expansion, and is within the limits at which it will fail structurally.

Much of this strength testing is due to the halo of hocus-pocus that attends patented combinations of tension metal and concrete.

All the structural requirements of heavily-loaded warehouses have been filled by beams 16 ins. apart, and a 1-in. wood floor, or by beams 4 ft. apart, covered by a 2-in. wood floor. The accomplishment of the same result on slightly greater spans with concrete and metal is, however, assumed to be an achievement of genius worthy to be attended with quiescent and drop loading and engineers' certificates. The tests that I propose are intended to develop elemental phenomena by which the fireproofing efficiency of constructions can be readily calculated without resorting to empiric methods. In formulating results it should be borne in mind that the fire records alone are conclusive as to the ability of a material to outlast the fire, the experiments are conclusive as to heat transmission only.

Fig. 1.—Elevation and Section Showing General Scheme of Gas Burner Test for Fireproof Construction.

Fig. 1 shows the proposed apparatus. It consists of gas burners such as are used on gas ranges

arranged so as to form a connected line 20 ft. long. A frame of fire brick set in fire clay is built up around the burners. Ordinary illuminating gas is used at a good pressure. Fig. 2 shows the apparatus arranged for the first experiment. The beam is 20 ft. long and is blocked up at the ends. Thermometers are attached to the beam with bulbs in connection with the lower flange. The flange is then covered with mineral wool to represent the impermeable mass of material enveloping the upper part of the beam, as shown by Fig. 3 of the typical construction of Class 2. The beam should deflect almost immediately and before the mercury rises appreciably. Fig. 4 shows the apparatus ready for a series of experiments designed to test the efficiency of the protection afforded by construction of Class 3. The beam in the experiment is placed upon ⅝-in. slabs of hard tile extending the whole length of the apparatus. The thermometers and mineral wool are set in place as before. After a few minutes' application of heat the bottom flange of the beam should expand and one or both ends curve upwards. The experiment may be repeated with other materials in place of the hard tile: (1) Porous tile; (2) plaster of Paris; (3) concrete; (4) common mortar and wire cloth; (5) patent mortar and wire cloth.

Materials 4 and 5 may be re-enforced with a thickness of tile, concrete, plaster and mineral wool. Experiments are to be made with various combinations in varying thicknesses up to the point where the beam is unaffected in one hour of test. Figs. 5 and 6 show typical constructions for which the foregoing is a test.

Fig. 7 shows the tubular lintel construction. To test the air protection of this system arrange the apparatus as in Fig. 4, with the addition of an air space under the beam. The experiment may be varied to ascertain the air space required and by admitting air from outside the area of air duct necessary to keep the beam unaffected in one hour's test. Fig. 8 shows a common construction of Class 4. If the beam in Fig. 4 is blocked up 4 ins. above a thickness of wire cloth and plaster, the value of the air space will be arrived at. Requirements to protect may be arrived at by air inlets and thicknesses of plaster and mineral wool. The test indicated in Figs. 9, 10 and 11 is designed to show the requirements of the construction shown in Figs. 10 and 11. Fig. 9 shows the test of the construction in its cheaper form. Increases of protection by means of plaster, mineral wool and air inlets may be tried. The beams and air spaces should not exceed 300° temperature at the end of one hour. Fig. 12 is an experiment to show the comparative penetration of heat at the ceiling and horizontally at different levels. It will show that any adequate ceiling device will more than suffice as a covering for vertical supports. The apparatus may be made of partition tile built around a single burner. The temperature of the different air spaces at regular intervals will develop clearly the various ratios of absorption by heat.

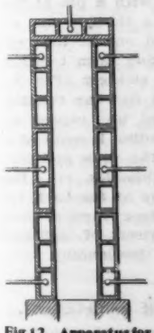


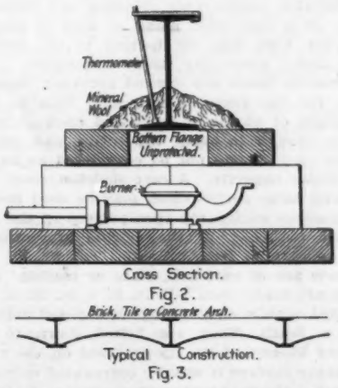
Fig 12. Apparatus for Showing Comparative Penetration of Heat Horizontally at Different Levels.

Similar tests on a small scale performed five years ago by myself indicated that a 11-16-in. tile slab reaches 300° F. temperature in seven minutes' exposure to gas heat, increasing thereafter at 50° F. per minute, and that the ratios of protection to thickness of tiles were as follows:

Thickness.	Protection.
1.	1.
2.	3.
3.	5.
4.	7.
5.	9.

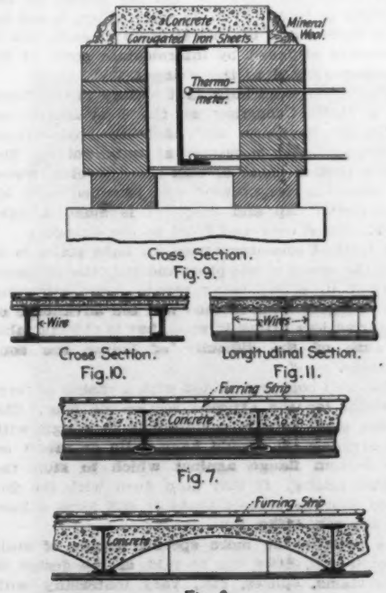
Concrete thicknesses were, if anything, less protective than tile. Plaster of Paris thicknesses were an absolute protection until calcined. Mineral wool, by reason of non-penetration of heat, formed an absolute protection. Wire cloth and common plaster were about the same as the thin tile. I have reason to believe that the experiments suggested above will demonstrate that the additions of a wire mesh holding the plaster to a 1-in. or 1½-in. tile slab will form a sufficient protection, and that wire cloth and a covering of mineral wool will, in combination with the plaster form a sufficient protection. Plaster of Paris blocks may also be introduced or thicknesses of concrete or plaster on top of the wire mesh.

The object of the tests is to develop such a degree of protection that a 20-ft. beam of average depth shall not distort at all or lengthen ⅝ in. in one hour's exposure. Confined air spaces and floors must not exceed 300° F. temperature, 68° or 70° to be assumed as normal. All moisture is to be excluded by preliminary warming, followed by subsequent cooling to normal. Readings of thermometers are to be taken every minute with thin coverings, every five minutes with effective devices. Gas pressure is to be such as to produce heat equal in intensity to flames produced by combustion of merchandise in large areas. A burner, such as is used in gas ranges and small china kilns, will produce this heat.



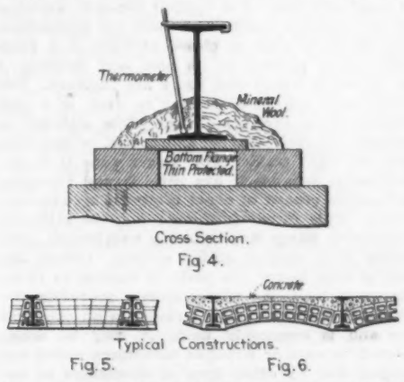
Figs. 2 and 3.—Method of Applying Gas Burner Test to Unprotected Metal Constructions.

The expense of the above series of tests may be greatly reduced by using the full length apparatus on one material only, to establish a starting point for comparative tests on all materials with one or two burners and thermometers without beams.



Figs. 7 to 11.—Method of Applying Gas Burner Test to Constructions in Which the Finishing Material Forms the Fireproofing.

If the Committee on Fireproofing Tests of New York city, or any of the engineering departments of our universities and schools of technology, will elaborate and perform the experiments described in the foregoing, the missing links in our knowledge of the art of fireproofing will be supplied, and a correct practice instituted which, checked by observations of future fires, may easily result in the same standard of perfection that has been reached in the purely structural arts.



Figs. 4 to 6.—Method of Applying Gas Burner Test to Constructions in Which the Constructive Material Forms the Fireproofing.

METAL STAIR DESIGN.

By Karl. Burghardt.
(With insgt.)

The universal demand for fire proof buildings, and the resulting keen competition among architects and engineers for the production of structures in the highest degree non-combustible, even to the smallest fittings, has brought the iron stair into general use. As a most important feature in any building, furnishng the only reliable means of communication between floors, it is necessary that the stairway be entirely fireproof. In many localities it is required by law that buildings of a commercial nature, in which many persons are employed on the different floors, shall be provided with stair wells entirely inclosed by fireproof walls, and have iron stairs. The necessity for this is shown by the numerous accounts of fatality by fire, which have resulted from the fire finding its way up the stair well and thus cutting off all means of escape.

In office and other public buildings where ornamental detail is considered, the iron stair is desirable from an architectural point of view. Necessarily conspicuous in such a building on account of its importance, the stair is often a principle feature of the interior design. The readiness with which iron, wrought or cast, lends itself to ornamental work, and the light, yet strong appearance it presents, recommend it to the favor of the architect. To the engineer it offers a firm and light form of construction in a material the value of which he knows and can figure with exactness.

The parts of a stair are: The stringer girders, risers crossing and resting on these stringers, and treads supported by risers and stringers and forming the step. All exposed sides of the stair and well hole are provided with a guard rail which is stiffened by newel posts. The well hole, unless otherwise provided for, has a casing or face plate to form a finish.

The arrangement and primary design of a stair are effected by the general conditions of space and height, and are usually laid out by the architect. The proportion of rise to tread should be such as to give an easy run to the stair. A convenient rule, and one that works out well for ordinary conditions, is to make the sum of rise and tread approximate 17½ ins. A rise of from 6½ ins. to 7¾ ins. and tread of 10 ins. to 12 ins. gives an easy stair for ordinary purposes.

For computing the sections required the load may safely be taken at 100 lbs. per sq. ft. of surface on plan, the span of the stringer being considered as its actual length between supports. The depth and form of stringer required is usually fixed by the ornamental design as furnished by the architect.

The stringer or carriage is the girder to which

the treads and risers are fastened, and by which they are supported. It is known as closed or open, as it covers and forms a finish for the ends of tread and riser, or is entirely beneath, allowing them to project and form a finish for themselves. The simplest form of closed stringer is a plate with knees riveted to its side and forming a lip to which treads and risers are fastened. For these knees a light angle may be used, or a cast bracket with projecting lugs. This stringer is suitable for stairs having short runs, or one used only for light traffic. For longer runs it is objectionable because it has little lateral strength, and unless braced at short intervals becomes insecure. This form of stringer may be stiffened by riveting flange angles to top and bottom, thus giving it a riveted girder section. Unless the load is very heavy the plate is figured to carry the whole load, the angles merely providing the necessary stiffness. This stringer is an excellent one and is commonly used. It may be ornamented by cast or wrought mouldings under the flanges, and by other lines of mouldings or rosettes on the web (Fig. 5).

Considerable ornamentation may be desired on the stringers so that the work can only be executed in cast iron. Unless the run is short a cast stringer is objectionable on account of the unreliability of cast iron as a girder and because of the difficulty in getting a straight casting. When used it is advisable to cast the rib with the lighter ornamentation separately and afterward bolt on the heavier moldings, rosettes, etc. The stringer thus formed may be strengthened by riveting wrought iron bars or angles to top and bottom edges or by a plate or rolled section placed behind and hidden by the casting. In the latter case the wrought iron may be figured to carry the whole load, the casting being made as thin as possible and forming merely an ornamental face plate.

When the stair is to be used only for light traffic, or the span is short, a plate wide enough to cover the end of tread and risers may give a section in excess of that required. In such a case the open stringer admits of a more economical section. The simplest form of open stringer is an angle or bar to which are riveted knees of cast or wrought iron, resting on the top (Fig. 4). Greater strength and stiffness may be obtained by using a rolled section I-beam or channel. If ornamentation is desired, the knee may be made of cast iron with mouldings and ornament in the center, and an apron dropping over the stringer and covering the joint (Fig. 6).

If the stair is very wide it may be advisable to use intermediate stringers. They must necessarily be of the open type, and may be any of the sections mentioned. If the soffit of the stair is to be ceiled it is desirable to have the stringer flanges flush on the bottom. If an intermediate stringer is required the outside stringers may have to be excessively deep to bring their bottom flanges flush. The depth of the intermediate stringer may be reduced by figuring the outer ones to carry the whole load and framing between them small cross beams at intervals which in turn support the center stringer, thus reducing its span and consequently its depth.

The stringer may be required to present a heavy appearance, as for example the main stairway of a court house. In this case the carrying stringer may be of wrought iron as here described, and entirely surrounded by a cast box suitably molded and ornamented. The inside section of this box may be arranged to rest directly on the supporting stringer and have the necessary lip for supporting rise and tread cast on its side (Fig. 3).

The rises may be of wrought or cast iron, and are generally from 3-16 in. to ⅜ in. thick. Cast iron is preferable as it admits of considerable ornamental detail, which is usually desired. The risers are often made with a perforated pattern in the panel to admit light. The riser should be provided with projecting lips on top and bottom which give bearing for the treads and through which the treads are bolted. In case of the cast iron these lips are cast on, being notched out where the riser rests on the stringer knees.

If the rim has a wrought plate, the lips are made of light angle irons, riveted on. If a cast-iron tread and riser are desired they may be cast in one piece, with a connecting rib at the ends, which is bolted directly to the stringer plate, thus doing away with the necessity of knees on the stringer. If this method is adopted, these end ribs should be provided with heavy chipping strips, as the irregularity in length of castings necessitates considerable grinding and fitting in shop. If a cast riser alone is used it may be provided with lugs for bolting to the stringer plate direct, answering the same purpose.

If marble risers are desired provision must be made for the support of treads. This is done by means of angles at front and back of tread, strong enough to carry the entire load, as the marble riser should not be considered as having any girder capacity. A cast skeleton riser, i. e., one with large perforations, may be used instead of the above angles, the open pattern of the riser against the color of the marble presenting a neat appearance from beneath.

Treads are of cast iron, slate or marble. Cast treads are made from 5-16 in. to ½ in. thick, and provided with a cast nosing on exposed sides to form a finish. They are bolted down to the stringer knees and the lip provided on the riser. The upper surface is usually corrugated or cut in diamond pattern to give more secure foothold. The cast tread may be strengthened by casting cross ribs on the bottom. Slate or marble treads give a better appearance and are much used. Generally they are fastened in place securely enough if bedded in cement especially if the riser is provided with two or three small dowel pins on the top flange. They may be further fastened by bolts or by wood screws driven from below into wood plugs inserted in the tread. They are made from 1¼ in. to 2 ins. thick.

The exposed sides of stair and well hole must be provided with a rail strong enough to withstand the weight of persons leaning against it. The rail is stiffened at the corners by newel posts. Rail and posts form a considerable feature of the ornamental design and are usually so treated. The rail consists of a hand rail of wood or iron and provided with balusters of cast or wrought iron which may rest on the top flange of the stringer or be bolted to its side. (Figs. 5 and 6.) It is fastened to the newel posts at ends and if necessary stiffened by intermediate posts or by brackets riveted to the stringer.

The newel is an important feature in the finish of a stair. Occurring at the intersections of stringers it hides the unsightly connections which are often necessary at these points. The newel post is made of cast iron, paneled, fluted or otherwise ornamented and provided with an ornamental cap and drop. It is made a light shell, slotted over and fitted to the stringers

A method sometimes used for light stairs is to cast the newel in one piece and stop the stringers against it, a lug being provided for attaching the stringer. This method has the advantage of requiring less fitting in shop, but is objectionable because of the difficulty of hiding the connections.

The well hole is provided with a casing to form a finish for the exposed section of floor. The casing plate usually corresponds in design with the stringer. It should have a lip or rabbit on the bottom flange against which to stop the plaster ceiling. It may stop flush with the finished floor, or project above it and form a base for the rail. (Fig. 5.)

As regards the more specific details of stair construction, little can be said, as the design of connections, splices, etc., vary materially with the conditions imposed. Although stairs are occasionally required of long span and considerable width which require strong and heavy connections, yet the majority are of such short run, and the stringer section required to fulfill the architectural features so much in excess of that required to carry the load that the connections, if figured out exactly, would appear ridiculously small in proportion. The main point in designing such connections is to obtain a neat appearance without requiring too much work in fitting.

The stair shown in Fig. 7 may be taken as an illustration. It is enclosed on three sides by a brick wall and provided in front with a guard rail on the landing. The wall stringers are preferably made of the closed type with flanges returned back against the wall and forming a base for wainscot or plastering. The outside or face stringer may be open or closed. Let us consider it as a closed stringer formed of a wrought plate with top and bottom flange angles, ornamented by cast mouldings. The risers are cast iron and the treads slate. The wall stringer W 1 has an angle iron shoe at the bottom (Fig. 9) and runs into the brick wall at the upper end. Stringer W 2 runs into the wall at one end and frames into W 1 at the other. W 3 frames into W 2 and into the header beam (Fig. 5). The face stringer F 1 is provided with an angle iron shoe resting on the floor (Fig. 9), and connects with F 2 as shown in Fig. 8. This connection is braced by continuing the stringer F 1 under the platform to W 2. A light T-iron is framed between this stringer and W 1 to form an intermediate support for the platform. The connection between stringers F 2 and F 3 is made in a similar manner, F 2 continuing to and framing against W 3. The upper end of stringer F 3 is cut to frame into the header beam as shown in Fig. 5. In all these face stringers the flange angles and moldings are stopped against the newels, the plate alone running into the newel. The newel posts are slotted to fit over the stringer plates and are made in two parts arranged so that they may be slipped over and fitted to the stringers after the latter are connected. The hand rail is of wood with wrought iron balusters.

The casing plate (Fig. 5) has the same section as the face stringer and is fastened to the header beam at intervals by iron furring strips. It may be run through the newel post and be connected with the stringer F 3, or, preferably stop against the newel and connect to it by small angle clips.

Fig. 1 shows an ordinary form of construction for a circular stair. The riser and tread are of cast iron made in one piece with a connecting web at the end (Fig. 2). The center post for the stair is a heavy gas pipe over which the tread and riser bracket is slipped, a thimble being cast on the inner end for that purpose. The rail balusters are of wrought iron rods shouldered and provided with a pin at the bottom which passes through a thimble cast on the outer end of the riser and one at the rear corner of the tread below, bolting them together and thus forming an outside stringer (Fig. 2). The hand rail is formed of a flat bar through which the balusters are riveted, and capped by a half oval bar. The upper landing is made of a cast plate cut to a quarter of the circle and provided with riser, end web, thimbles, etc., the same as a tread, and with lugs at the back for bolting to the header beam in floor framing. Care must be taken to make the risers of sufficient height to get headroom under this landing.

THE MANUFACTURE AND USE OF SAND-CEMENT.

A kind of cement which is rather new in this country, but which is extensively used abroad, is what is known as Silica-Portland cement, or, more commonly, as "sand-cement." This is not a mere mixture of sand and cement, but is a distinct product obtained by grinding sand and cement together (in any desired proportions) to an almost impalpable powder. This material is used in the same way as ordinary neat cement, being mixed with ordinary unground sand on the work in proportions varying with the character of the work and the use to which the cement or cement mortar is to be put. The advantages claimed are a greatly increased density and tensile and compressive strength as compared with ordinary sand mixtures, so that cement mortar made with sand-cement and sand will be superior to that made with ordinary Portland cement and sand, although the former will contain a less proportion of Portland cement.

This sand-cement is the invention of Mr. F. L. Smidth, of the firm of F. L. Smidth & Co., Copenhagen, Denmark, and it has been used extensively during the past four or five years for harbor and railway works, gas works, schools and other build-

ings, and for general concrete and masonry work in Europe. Among other special works are the dock walls, etc., of the new harbor at Copenhagen; a sewage pumping station, gas works and public schools in the same city; structures on the Danish State Railways, and bridges and other works for the new Kunda-Wesenberg Rail-

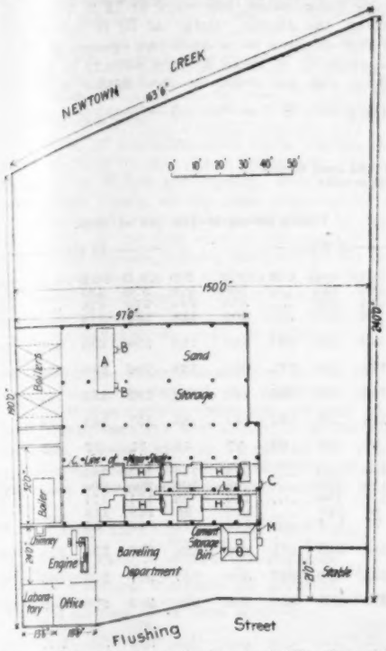


Fig 1.—Plan of Works of the Standard Silica Cement Co.

way in Russia. Manufacturing plants are now in operation or contracted for in France (at Boulogne), in Germany (at Hamburg), in Russia (at Port Knada, Novorossik and St. Petersburg), and in Denmark, Sweden and Italy. In England, but little has been done towards introducing this cement, on account of the extremely low price of Portland cement. The sand-cement is now being introduced in this country, and one manufacturing plant is already in operation, while other plants are being arranged for, as it is considered advisable to avoid carriage for long distances by rail. Very satisfactory results have been obtained by tests made by Mr. Alphonse Fteley, Chief Engineer of the Aqueduct Commission of New York city; by Prof. W. H. Burr, of Columbia College; by Mr. W. W. Maclay, of Glens Falls, N. Y., and others. About 6,000 barrels, of 1 to 1 sand-cement, mixed with three parts of building sand, have been used for the massive concrete foundations of St. John's Cathedral, New York, which foundations will comprise about 13,000 cu. yds. of concrete, and the sand-cement has also been used in the foundations of the extension of the Altman Building.

In ordinary Portland cement mortar, 1 part of cement is used to 1, 2, 3 or 4 parts of sand, according to the purpose for which it is to be used, but if greater proportions of sand are used in order to make a cheaper mortar, as in cases where great strength is not essential, there is difficulty in properly and thoroughly mixing the two ingredients, while the strength of the mortar after setting decreases very rapidly as the proportion of cement increases. The mortar in these cases is incoherent and very difficult to work with the trowel, while the exact reverse is the case with sand-cement mortar. This is due to the fact that the purpose of the cement is to cement together the particles of sand, and if there is a very small proportion of cement, it is difficult to ensure a thorough and complete coating of the sand particles. The finer the cement the greater will be its coating properties, but there is considerable difficulty in securing by ordinary methods a thorough and uniform mixture or combination of sand and very fine cement, the latter being liable to clog so that some parts of the mixture will have too little and other parts too much cement, with consequent inferiority of mortar.

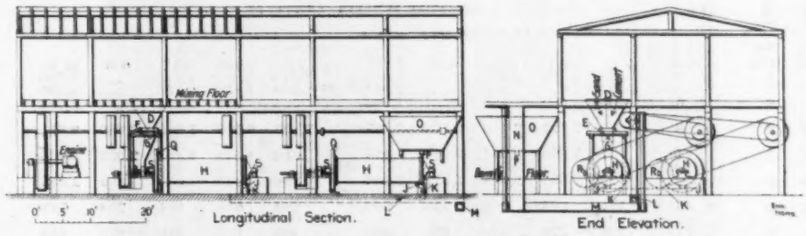
In addition to the use of sand-cement in masonry and concrete work, its cheapness will enable it to be used as a substitute for lime mortar in the plastering of buildings, and one important advantage in such use will be the much greater rapidity of drying, so that rooms may be safely occupied much sooner than where lime plaster is used. For dock walls, etc., where concrete is liable to become more or less porous from the action of the sea water, the sand-cement is specially adapted, and is much safer than Portland cement mixed with ordinary sand, on account of its greater density.

Tests of the crushing strength of the concrete used for the St. John's Cathedral foundation were made by crushing 6-in. cubes of the concrete, which were composed of 1 part sand-cement (1 : 1), 2 parts of unground sand and 3 parts gravel. The average results were 77,162 lbs., 83,225 lbs. and 92,465 lbs. for cubes, 7, 14 and 30 days old, respectively. The tests of tensile strength of the cement used showed the following results as the average of a large number of briquettes tested:

	——Lbs. per sq. in.——		
	7 days.	14 days.	28 days.
Sand-cement (1 : 1) and 3 parts sand..	156	188	200
Portland cement and 3 parts sand (average tests of 15,208 barrels)...	137	170	179

The foregoing particulars will suffice to show the practical advantages offered by and the general applicability of sand-cement, and we may now proceed to describe the plant now in operation at Long Island City, N. Y. This is owned by the Standard Silica Cement Co., of Glens Falls, N. Y., the New York offices of which are at 156 Fifth Ave. Mr. T. S. Coolidge is President; Mr. W. W. Maclay, M. Am. Soc. C. E., (President of the Glens Falls Portland Cement Co.), is Vice-President, and Mr. Charles H. Spencer is General Sales Agent of the company. To these gentlemen, and to Mr. Greene, Superintendent of the works, we are indebted for drawings and information used in the preparation of this article.

The plant is located near the terminal station of the Long Island R. R., and has a frontage of 150 ft. on Flushing St. and 163 ft. 6 ins. on deep water on Newtown Creek. It is thus convenient to the ferry for cartage to New York, while canal boats or lighters with cement in barrels or in bulk can be unloaded at the works, or the finished product can be loaded in the same way for water transport. The plant covers an area of about an acre. At present only two grinding mills are in operation, with a daily capacity of 250 barrels; four more are in the building ready to be set up, while space has been provided for still two more, or eight in all, which will give a total capacity of 2,000 barrels per day, running day and night.



FIGS. 2 AND 3.—SECTIONS SHOWING MACHINERY OF THE STANDARD SILICA CEMENT CO.

Fig. 1 is a general plan of the works, showing the four mills already provided, and the positions of the four additional mills, and the new engine and boilers which are to be put in. Fig. 2 is a longitudinal section, and Fig. 3 a cross section showing the arrangement of the machinery.

The cement and sand as received are stored on the main floor. The sand is dried in a Cummer sand drier, A (heated by a coke furnace), and then raised by an elevator, B, to the mixing floor. The cement is raised to this floor by an elevator, C, having curved arms to hold the barrels and bags. The sand and cement are shoveled or dumped into the hoppers D, D (one to each mill), each of which is divided by a central partition, the sand being thrown in on one side and the cement on the other. Wire screens over the hoppers hold back pieces of clam shells, paper, or other foreign matter. At the bottom of the hopper, D, is the automatic meter, E, which regulates the proportions of sand and cement,

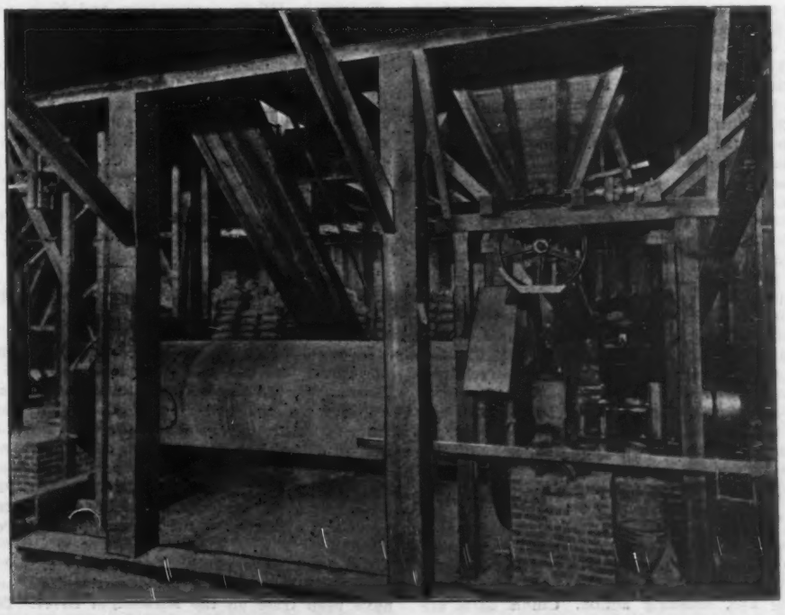


FIG. 4.—INTERIOR VIEW OF WORKS OF STANDARD SILICA CEMENT CO., SHOWING ROTARY GRINDING MILL.

different proportions being obtained by driving the meter at different speeds by the cone pulley F. From this device the sand and cement fall through the shoot, G, to the hollow bearing of the mill cylinder, through which it is fed into the cylinder by a small spiral conveyor. In the revolving mill cylinders H, H, the sand is ground and mixed with the cement by means of smooth flint pebbles, moving about incessantly through the mass of sand and cement, the output at J being a very fine powder. This finished product is then carried by spiral conveyors K, L and M to the elevator N, by which it is raised to the storage bin O, at the base of which is the chute P for filling the bags or barrels with cement.

The cylinders and meters are manufactured by F. L. Smidth & Co., of Copenhagen, the sole owners of the patents, and are imported to this country. The cylinders are of 1½-in. boiler iron, 50 ins. diameter, and 18 ft. 9 ins. long, and weigh about 11,000 lbs. each, including the circular rack and the journals. At the charging end of the cylinder is the rack S, 90 ins. diameter, driven by the pinion R, by means of belting from the main countershaft. The cylinders revolve on the bearings S, S. The pinion R makes 200 revolutions per minute, and the rack Q is geared to give the cylinder 26 revolutions per minute. The cylinder is lined with special glazed tiles or bricks about 4 ins. long, ¾-in. wide and 1½ ins. thick, set on edge, in an extremely hard cement. In the cylinder is put a charge of about 4½ tons of grinding pebbles, and the charge of combined cement and sand is about 4½ barrels, the output of finished sand-cement being about 6 barrels per hour.

The grinding pebbles are extremely hard and tough flints, with a smooth surface, and of approximately flattened globular shape, about 2½ to 3 ins. diameter and 1 to 1½ ins. thick. These are imported from Iceland and Greenland, in assorted sizes. As the individual pebbles are not heavy, they have simply a grinding and not a crushing action on the sand, although in some mills (specially designed for the great weight) hard steel balls are used, which have a combined grinding and crushing action. China balls are also used to some extent, but are expensive. The pebbles must of course be harder than the sand, but wear gradually smaller, the proportion of the ground flint in the finished product, however, being too small to be appreciable. Almost any sand may be used, as long as it is clean and free from impurities, and specially free from iron. At the works here described, sharp, fine sea-sand from Rockaway is used, and is not washed to get rid of the salt, but simply dried and screened. The color of the sand will of course affect the color of the sand-cement.

The cement used is the Ironclad brand of the Glens Falls Portland Cement Co., and the standard proportions of sand-cement for the market are 1 to 1 and 1 to 6, the former being principally used. Any other good brand of Portland cement may be used if desired by the purchaser. The degree of fineness of the sand-cement is such that only 5% remains on a sieve of 180 meshes, or 32,400 per sq. in. For this reason it has to be carefully packed, extra heavy paper being used, as the cement will find its way through almost any barrel. The sand-cement is packed in 400-lb. barrels, 130-lb. canvas bags and 95-lb. paper bags.

The accompanying table gives the results obtained with sand-cement in Europe, but it is to be noted that the sand-cement of which the tests are given was ground some year ago, and about 20% was rejected by a sieve of 32,000 meshes per sq. in., while the sand-cement manufactured by the Standard Silica Cement Co. now gives a residue of only 5% on that sieve, as already noted. The breaking strengths recorded in the table are therefore considerably lower than those now obtained with the more finely-ground cement.

FOREIGN TESTS OF SAND-CEMENT.

(The American sand-cement is much finer than that used in the tests recorded below, and gives much higher results.)

Mixture by weight. Cement.	Sand.	Sand.	The Mixture contains. Cement.	Sand.	Crushing Strength—Lbs. per sq. inch. In Water 7 D	28 D	90 D	6 M	12 M	In Air 7 D	28 D	90 D	6 M	12 M	Tensile Strength—Lbs. per sq. inch. In Water 7 D	28 D	90 D	6 M	12 M	In Air 7 D	28 D	90 D	6 M	12 M
Sand-cement.		Not grd																						
1		3	1	3	1,595	2,360	3,420	....	5,055	1,640	2,500	3,160	....	3,720	256	327	412	....	500	270	370	455	....	611
1		3	1	3	1,165	1,610	2,150	....	2,967	1,280	1,870	2,400	....	3,295	213	284	356	....	356	284	370	426	....	582
1		6	1	6	426	655	868	....	1,292	526	952	1,110	....	1,760	85	128	185	....	200	114	185	213	....	221
1	2	2	1	8	1,080	1,795	2,148	2,578	3,365	1,122	2,150	1,565	3,330	2,911	142	242	299	384	400	185	356	356	526	526
1	3	2	1	11	497	1,080	1,637	2,008	2,485	610	1,575	1,408	2,022	3,536	114	185	228	271	326	128	256	256	313	440
1	6	2	1	20	327	555	1,025	1,117	1,363	398	880	967	1,209	1,292	71	128	185	228	242	114	242	242	242	242
1	12	2	1	38	171	384	726	796	866	256	610	654	768	767	43	114	128	157	142	85	157	142	148	156
1	24	2	1	74	128	270	370	370	383	100	298	248	271	213	28	57	57	57	57	43	71	57	57	57
1	6	0	1	6	512	895	1,380	....	2,357	600	1,120	1,460	....	2,258	85	114	185	....	312	114	185	185	....	213
1	6	1½	1	16½	370	540	852	....	1,576	440	940	960	....	1,533	71	114	185	....	298	100	200	200	....	213
1	6	2	1	20	200	384	667	....	1,050	256	682	725	....	1,079	57	114	156	....	220	85	171	171	....	156
1	6	2½	1	23½	142	284	540	....	738	200	568	583	....	710	43	86	128	....	128	85	128	114	....	114
1	6	3	1	27	114	228	426	....	582	171	455	468	....	610	43	71	1 4	....	142	71	85	85	....	99
1	3	2	1	11	497	1,080	1,637	2,008	2,485	612	1,595	1,408	2,022	3,496	114	185	228	271	326	128	256	256	313	440
1	3	2	1	11	640	1,500	2,136	2,702	3,081	625	1,780	1,908	3,160	3,081	142	242	280	327	356	157	327	270	456	460
1	3	2	1	11	670	1,220	1,651	2,462	2,670	725	1,025	1,671	2,802	2,868	142	213	265	327	376	200	313	270	449	500
Test of Joint ⅜-in. thick.																								
1	3	2	1	11	....	....	....	....	....	2,675	3,120	3,510	3,791	....	....	....	....	....	....	....	....	....	....	....
1	12	2	1	38	171	384	....	....	....	256	610	653	769	....	43	114	....	....	....	85	157	....	....	....
1	12	2	1	38	....	....	....	....	....	342	600	710	738	....	....	....	....	....	....	....	....	....	....	....
1	24	2	1	74	....	....	....	....	....	100	300	249	270	....	....	....	....	....	....	....	....	....	....	....
1	24	2	1	74	....	....	....	....	....	213	412	370	454	497	....	....	....	....	....	....	....	....	....	....

THE PROPOSAL TO IMPROVE MISSISSIPPI RIVER NAVIGATION BY CONTRACT.

In our issue of March 12 we briefly commented on House bill No. 2779, authorizing Isaac M. Mason, W. M. Samuel and their associates to improve the channel of the Mississippi River, from St. Louis to Vicksburg, for the sum of one million dollars per annum. Our attention has recently been called to some very pertinent remarks upon the same subject by Mr. Henry Flad, Past-President of the American Society of Civil Engineers and a member of the Mississippi River Commission.

Mr. Flad says, first, that the efficiency of movable dikes is still problematical, as none have been tried on the Mississippi River. They might be successfully used in closing channels and in directing currents; but on long bars they would simply cause the removal of sand from one place to deposit it at another lower down. Some other devices mentioned in the bill are also equally doubtful in practicability, and some have been tried and found to fail in all save exceptional cases.

On the other hand, dredges have been fully and successfully tried in this work. They take up the sand and actually remove it to points remote from the channel, and where it can not be returned by the current of the river. Dredges have the advantage over jetties and movable dikes of being able to begin work before the river has reached its lowest stage; as the dredge "Alpha," belonging to the Commission, can work at 12 ft. below the surface, the dredge "Beta" at 20 ft. below, and the new dredges to be built can operate at 15 ft. The capacity of these dredges already in hand is 600 cu. yds. per hour, for the "Alpha" and over 5,000 cu. yds. per hour for the "Beta." Mr. Flad believes that these two dredges would be sufficient to keep the river free from obstruction by bars from Cairo to Memphis, and provide a channel 250 ft. wide and 9 ft. deep throughout.

Messrs. Mason & Samuel propose a channel only 6 to 7 ft. deep and 100 ft. wide above Cairo and 150 ft. wide below Cairo. This width, Mr. Flad declares, is entirely insufficient for the safe passage of boats. For the above work Messrs. Mason & Samuel would receive, under the bill, $600,000 per annum for creating and maintaining a channel 7 ft. deep and 150 ft. wide up to Cairo, and $400,000 per annum for a channel 100 ft. wide and 6 ft. deep, from Cairo to St. Louis. For each additional foot of depth secured they would receive $50,000 per year above Cairo, and $100,000 per year below Cairo. Mr. Flad points out that in 1882 and 1885 the lowest water in the river was never below 8 ft., and in 1890 it was never lower than 10 ft. This may occur in the next 20 years; and under similar conditions the contractors would receive a bonus of $200,000 for the two years of 8-ft.-depth, and $300,000 for the one year of 10 ft.; adding the stipulated annual sums, the contractors would receive $1,800,000 plus $500,000, or $2,300,000 in these three years, without incurring any outlay whatever except for the maintenance of plant and for watchmen.

Mr. Flad then contrasts this exhibit with the work to be done by the Mississippi River Commission under its present organization. He finds 50 crossings between St. Louis and Cairo, and 53 between Cairo and Vicksburg, on any of which bars may appear and obstruct navigation. He then has a profile made, on the basis of the low-water season of 1895, and figures the total probable quantities of excavation as follows: Above Cairo, channel 100 ft. by 6 ft., 55,220 cu. yds.; for a channel 250×9 ft., 1,471,420 cu. yds. Between Cairo and Vicksburg, for a channel 150×7 ft., 222,786 cu. yds.; for a channel 250×9 ft., 1,682,520 cu. yds.

He estimates that with an average capacity of

800 cu. yds. per hour, 7 dredges and dredging plants would be needed between St. Louis and Cairo, and 9 dredges and plants from Cairo to Vicksburg. If channels of the depth and width proposed by Messrs. Mason & Samuel are to be secured, sets of 3 and 4 dredges of the same capacity would do the work. Mr. Flad estimates the cost of one dredging plant of 800 cu. yds. capacity, as follows:

One dredge	$100,000
One pile sinker	5,000
One tender	25,000
One surveying launch	1,000
One fuel-flat	1,000
Total for one plant	$132,000

The cost of operating one such dredge and plant, as fixed by one year's experience with the "Alpha," is $5,500 per month. For one year's work about Cairo, on the plan proposed by the Commission, the cost would be $214,500; to this is added 10% of the first cost of the plant for renewals and repairs, making $306,900 for the total cost of operation for all dredges for one year; or $6,138,000 for 20 years. From Cairo to Vicksburg, on a similar basis, the cost of operation would be $349,800 per year, or $6,996,000 for 20 years.

Applying the same assumptions to the plan of Messrs. Mason & Samuel, the operating expense of their dredges above Cairo for one year would be $127,600, with the 10% added; or $2,552,000 in 20 years. From Cairo to Vicksburg the annual cost would be $157,300; or $3,146,000 for 20 years. Mr. Flad summarises these two exhibits as follows:

Channel 250 × 9 ft. above and below Cairo.

First cost:	
St. Louis to Cairo, 7 dredges and plants at $132,000	$924,000
Cairo to Vicksburg, 9 dredges and plants at $132,000	1,188,000
Operating expenses, for 20 years, as above:	
St. Louis to Cairo	6,138,000
Cairo to Vicksburg	6,996,000
Total	$15,246,000

Channel 100 × 6 ft. above Cairo, and 150 × 7 below Cairo.

First cost:	
St. Louis to Cairo, 3 dredges and plants at $132,000	$396,000
Cairo to Vicksburg, 4 dredges and plants at $132,000	528,000
Operating expenses, for 20 years, as above:	
St. Louis to Cairo	2,552,000
Cairo to Vicksburg	3,146,000
Total	$6,622,000

If Messrs. Mason & Samuel would carry out their contract for 20 years they would receive $20,000,000 for work costing at most $6,622,000.

If years like 1882, 1885 or 1890 were to occur during that period, the expense to them would be lessened, as they would have to do little or no dredging, and would at the same time receive a bonus for the additional depth, due to the natural flow. The navigation interests, however, would not be satisfied with the channels proposed by Messrs. Mason & Samuel, and if they should, therefore, conclude to adopt and maintain the channels proposed by the Commission they would receive the $20,000,000 plus a bonus of $7,000,000 for the 3 ft. additional depth above Cairo and the 2 ft. additional below (at $50,000 and $100,000 per annum per foot). This would make the cost $11,754,000 more than the same work could be done for by the Commission; the relation being as $27,000,000 is to $15,246,000, or an excess of nearly 50% in cost.

Since the above estimates were prepared Messrs. Mason & Samuel have increased their proposed channel width to 200 ft. above and 250 ft. below Cairo. This would increase their expenditure in 20 years about $10,000,000 and reduce their profit to about the same sum. As it would be difficult to determine whether or not the terms of any contract were fulfilled, the employment by the government of a considerable number of surveying parties and inspectors would be necessary. This would involve extra expense, which should properly be considered, with any contract plan.

FIREPROOF SHUTTERS IN THE RUSSELL & ERWIN FIRE.

A few weeks ago a fire started in one of the buildings of the Russell & Erwin Mfg. Co., the well-known manufacturers of hardware, at New Britain, Conn., and entirely destroyed it. The burned building was immediately adjacent to one of the main factory buildings of the company, but the fire was fortunately prevented from spreading to this, as the window openings of the adjacent building were all protected by corrugated fireproof shutters, made by the Berlin Iron Bridge Co..

The accompanying cut, reproduced from a photograph, shows the site of the fire. The building on the left had brick walls and wooden floors, and was completely gutted by the fire. We are informed that had the fire spread to the building on the right, the entire plant, covering several acres, and representing an investment of some $3,000,000, would probably have been destroyed. Mr. T. S. Bishop, M. Am. Soc. C. E., Assistant Treasurer of the Russell & Erwin Mfg. Co., in a letter written after the fire, says:

> The distance between the two buildings is about 15 ft., and the credit for stopping the fire in the passway in the direct line of the gale blowing at the time must be given to the efficient work of the firemen and the complete barrier afforded by the fireproof shutters and doors.

The above facts will, we believe, be found of interest in connection with the valuable discussion of the general subject of fireproofing, given in this and the preceding issues.

SITE OF FIRE AT WORKS OF THE RUSSELL & IRWIN MFG. CO.; NEW BRITAIN, CONN.
(Spread of Flames Stopped by Fireproof Shutters.)

TRESTLE FOR SINGLE-TRACK ELECTRIC RAILWAY.

(With inset.)

The extensive construction of electric railways within the past few years has called into service many engineers, who, although proficient in ordinary railway work, have had very little practical experience in laying out and constructing the roadbed, track and other line constructions for electric railways, and the complaint is often made by these engineers that engineering literature contains very little exact information of aid to them. This condition is a quite natural one, for the much more important problems of the best mechanical design for power plants and equipment properly takes precedence in such constructions to the more easy problems encountered in building permanent way and track. These last-mentioned problems are, however, deserving of more consideration than they have yet received in engineering literature and in our issue of Jan. 9, and again in this issue some of them are considered. At this point we may call attention to the fact that electric railway construction is gradually spreading out from city streets into suburban and rural districts, and naturally the question of roadbed and track construction is assuming to an increasing extent the features which characterise roadbed and track construction for steam railways. It is becoming, therefore, of increasing importance that this feature of electric railway work be studied by engineers.

The illustrations on our inset sheet this week show the details of a trestle designed and constructed for a single-track trolley line belonging to the Lehigh Traction Co., of Hazleton, Pa. Fig. 1 is a plan and profile of the trestle, which is constructed on a 3% grade and a curve of 350 ft. radius (16° 26'). Near one end the trestle crosses a street with a 25-ft. wooden truss span, but throughout its remaining length regular trestle construction is used. Fig. 2 shows the details of the truss span, and Figs. 3 and 4 details of the trestle bents at different points. Fig. 5 shows a plan of the floor system and the guard rails at the approach to the trestle.

The following is an abstract of the specifications upon which the trestle was built:

All timber shall be of first quality white oak, Pennsylvania yellow pine or long leaf Georgia yellow pine. It must be free from windshake, wanes, black, loose or unsound knots, worm-holes and all descriptions of decay. It must be sawed true and out of wind and full size. All framing must be done to a close fit and in a thorough and workmanlike manner. No blocking or shiming of any kind will be allowed in making joints, nor will open joints be accepted. All mortises and the shoulders of all tenons, and wherever two surfaces of timber touch, shall be painted with some preservative material, preferably white lead mixed with linseed oil or with coal tar. Both ends of all bolt holes and all surfaces of timber against which iron washers or separators are placed, shall be painted in the same manner. Cast-iron shall be used only for bolt washers and the ¾-in. separators between the two halves of each stringer. A washer shall be placed on each end of every bolt. All bolt holes shall be bored with an auger ⅛ in. less in diameter than the bolt for which they are bored. All ties, plates, clevises, bolts, drift-bolts, spikes, truss rods, etc., shall be of good quality wrought iron, and shall conform to the dimensions shown on the plan. Steel guard rails made from a section of rail similar to the main rails shall be laid along the inside of each rail for the full length of the trestle, and extend 20 ft. beyond each end of the trestle in the manner shown by the detail drawings.

Altogether 28,000 ft. B. M. of yellow pine timber were used in the trestle, which cost f. o. b. at Drifton, Pa., $19 per 1,000 ft. B. M. The cost of erection was $11.25 per 1,000 ft. B. M. The cost of cast and wrought iron was 2¼ cts. per lb. The cost of the foundations, which were stone masonry laid in cement mortar, was $3 per cu. yd. The trestle was designed by Mr. A. E. Hess, Engineer for the Lehigh Traction Co., to whom we are indebted for the matter from which our illustrations are made.

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So much public approval has been expressed of the proposition made by the Brooklyn Elevated Railways to lease the Brooklyn Bridge Ry. and run their cars over it, that the promoters of the scheme have been encouraged to propose terms for the lease which ought by no means to be granted, and will not be, if ordinary business principles are followed by those responsible for protecting the cities' interests. The bill to enable the lease of the bridge to be made, as introduced in the Legislature, provides that the lease shall be for the term of 50 years, and may be renewed for the same length of time. The annual rental is to be a sum equal to the average net earnings of the Bridge railway for a period of three years preceding the date of the lease. That is to say, the cities owning the bridge are asked to turn it over to these companies to operate for what it is now earning, regardless of the fact that the growth in the cities of New York and Brooklyn is absolutely certain to increase the traffic over the Bridge railway, so that the average traffic during the life of a 50-year lease would probably be at least double that on which the rental is based. Moreover, doubling the traffic, as every railway manager knows, will far more than double the net receipts. It is an axiom of railway operation that it is ADDITIONAL traffic that pays profits. The expense of operating the Bridge railway will not be very much greater when it is used by 90,000,000 passengers per annum than at its present rate of about 45,000,000 passengers per annum. The gross receipts, however, will be practically doubled.

In 1886 the number of passengers using the Bridge railway was 24,478,324. In 1895 the number was increased to 44,564,329. This growth of 20,000,000 in nine years was made notwithstanding the fact that during all that time the Bridge railway has been so overcrowded that travel by it has been exceedingly uncomfortable. With a system of operation installed by which passengers can go from the New York terminus to their destination in Brooklyn without change in cars, there can be no doubt that an enormous growth of traffic will at once occur and will rapidly continue, as Brooklyn continues to gain in popularity as a residence city for those doing business in New York. It would be preposterous with these facts plainly before them, for the cities of New York and Brooklyn to lease the bridge for a century or a half century on the basis of its present traffic.

The fact is that not one valid reason can be assigned for leasing the bridge for any such long term. Who is competent to say to-day what New York and Brooklyn will be 50 years hence? Were the New Yorkers of 1846 as good judges of the needs of the New York of to-day as are the present residents of the city? As a matter of fact, it is not a score of years ago since New Yorkers were giving away for a song valuable public franchises which, if their term had been limited as it should have been, would to-day be returning the city millions of dollars of revenue.

In a previous issue we expressed approval of the general plan of leasing the Brooklyn Bridge Ry., which has been proposed. It is a fact that the system by which a city owns such public works as street railways and lighting plants, and leases them to private corporations to operate is one of the very best that has ever been devised for the control of municipal monopolies. But all such leases ought invariably to be made for short term of years. One generation has no right to sell the rights that belong to another, and the organic law of every commonwealth ought to prohibit the granting of public franchises or the leasing of public works for any longer term than the life of one generation.

The danger in the use of square cast-iron columns, on account of the internal strains which are likely to be present in them, is brought forward in a communication printed in another column of this issue from Mr. John F. Ward, M. Am. Soc. C. E. We may say for the benefit of those of our readers who may know of Mr. Ward only as a civil engineer, that he was for some years at the head of one of the largest foundries in this country. His warning respecting the dangers in the use of square cast-iron columns, therefore, is not a mere theoretical assumption, but is based on long experience in foundry work. We know of no really substantial reason for the use of square instead of round cast-iron columns, if cast iron is to be used at all; and the questions raised by Mr. Ward are certainly worth serious attention from architects and engineers.

"The Indestructible Pile & Pier Co.," of No. 2 Wall St., New York city, which was exposed in our issue of Feb. 15, 1894, and again in our issue of May 16, 1895, appears to be still doing business but under a different name. Soon after our last exposure of the concern the gilt letters of the company's name in the directory in the hall of the office building at No. 2 Wall St. were painted out, and in their stead appeared the words "Railway & Dock Construction Co." The fact that the same rooms were occupied as before and the same name was set down as manager made us practically certain that it was simply the old scheme under a new name. We have heard nothing concerning its working, however, until this week, when we find in "The Indicator," an insurance journal published at Detroit, Mich., a full-page advertisement, together with a "reading notice" of several pages, by which it appears that "the Railway & Dock Construction Co. owns all the rights, titles, interests in, and the sole, absolute and exclusive right to manufacture and sell indestructible piles under United States patents." Again it is asserted that "applications are pouring in from engineers, contractors and railway officials all over the United States," and the dear public is cordially invited to invest in the stock at $10 per share (par value $100).

We have so fully shown up the character of this scheme in former issues that we need say little concerning it now. We are pleased to see that the promoter has this time refrained from using the name of the American Society of Civil Engineers, taking warning, doubtless, from our former remarks on this subject. It is, indeed, a pity that frauds should be allowed to go on reaping their harvest of victims from year to year without the slightest interference on the part of those whose duty it is to enforce the law. It is difficult to draw the line, doubtless, between the legitimate enterprise and the purely fraudulent concern; but when, as in many instances, there is no question as to where a concern belongs, the officers of the law are negligent of their duty if they do not suppress it and secure the punishment of those who carry it on.

In our issue of March 12 we paid our respects to the proposition to pay a St. Louis syndicate the comfortable sum of $1,000,000 a year for 20 years for keeping open a very shallow channel during the four low water months of the year, from St. Louis to Vicksburg. We have heard nothing concerning the fate of this proposition in Congress, and presume it has met the doom it deserved. Inasmuch as there may be some of our readers who may think we were unfair to this scheme, we have taken space to print on another page an abstract of the argument against it made by Henry Flad, Past-President of the American Society of Civil Engineers. In the light of Mr. Flad's figures, it looks as if the United States would indeed have paid dear for its whistle had it accepted the Mason-Samuel proposition. We learn that when the St. Louis delegation which went to Washington to boom this scheme realized the hopelessness of getting it through, they changed their tactics and asked instead that a contract similar to that which Messrs. Mason & Samuel proposed should be let to the lowest bidder. This scheme would have been a little better but not much. No responsible contractor will bid on work involving so many uncertainties and experiments without making a figure high enough to cover all contingencies. As a matter of fact, we believe that the navigation improvement of the Mississippi can eventually be carried out for very much less, even, than Mr. Flad's estimate. The new dredges of the Mississippi River Commission, one of which we shall shortly illustrate and describe, are likely to bring about a revolution in the improvement of alluvial river channels, and reduce the cost to an unprecedented figure.

The New York Legislature has passed the bill compelling railway companies to carry bicycles as baggage, and we may reasonably expect that other states will follow suit. The railway companies opposed the bill, but their influence counted for nothing compared with each legislator's knowledge of the fact that every bicycler among his constituents was watching his course with reference to the bill. Doubtless other states will follow the lead of New York, for things like these are contagious. The railways will do well to make the best of it and equip their baggage cars with some sort of overhead racks from which bicycles can be suspended and packed so as to occupy little room. If they do this we do not see that the carriage of bicycles is likely to involve any additional cost of much consequence to the railways, except on a few roads where traffic is heavy. Undoubtedly bicycling has affected local travel to some extent, and will do so more in the future; but on the other hand, it operates to cultivate the habit of travel, in a wonderful degree. The very extent of the carriage of bicycles by the railways shows how largely people use the trains to reach new points from which to start on tours with their wheels. If we add to this the amount of traffic which bicycle manufacturing and selling has given to the railways during these last three years when traffic was scarce, and consider also the stimulus to the good roads movement due to the bicycle and the traffic which road improvement gives to the railways, we believe that the bicycle will be found to have done the railways much more good than harm.

A good illustration of the reason why some cities fail to secure pure water supplies is afforded by the account in another column of the filtration schemes at Providence, R. I., which, within the past three years, have seemed on the point of being adopted, but which have not yet been carried out. At one time it appeared certain that mechanical filtration would be adopted, but an obstacle more apparent than real intervened just as the contract seemed about to be made, and the advocates of filter beds came quickly to the front. Their progress was then in turn impeded by the friends of mechanical filtration, and these last were aided at just the right juncture by the irrepressible artesian well advocate, who always bobs up at such times, re-

gardless of the existing geological conditions or the quantity of water required. Nothing has ever come of any of these schemes at Providence, but there is now talk of reviving the filtration idea. At the outset, the City Council appears to have been strongly in favor of mechanical filtration, but there has not come to our attention any indication that this was due to engineering advice. Throughout the discussion the city engineer, Mr. J. Herbert Shedd, M. Am. Soc. C. E., expressed himself, whenever called on, as in favor of sand filter beds. Requests for his opinion, however, were generally informal. In fact, the City Council instructed the Commissioner of Public Works to contract for a "suitable system of mechanical gravity filters" without any official recognition of the city engineer further than to ask him for an informal expression of opinion, and to make him one of a commission of three to approve the system selected before the contract was awarded.

When sand filtration came to the front it was doubtless largely through Mr. Shedd's efforts; but he had previously expressed himself as in favor of contracting for mechanical filters rather than none, and intimated his fear that nothing would be done for a long time unless a mechanical system was adopted, a prediction which has been fulfilled.

The agitation at Providence, however, has by no means been valueless. Filtration of some sort will probably be adopted there eventually, and the agitation led to a series of valuable experiments on mechanical filtration, made by Mr. Edmund B. Weston, M. Am. Soc. C. E., as recounted at length elsewhere in this issue.

These Providence experiments furnish far more data than has previously been available to engineers from any source regarding the methods and results of mechanical filtration as a means of removing bacteria from water. Aside from indicating that a high and continuous bacterial efficiency can be obtained with properly constructed and carefully operated mechanical filters, the experiments seem to show conclusively some other things which we have tried to bring out in our abstract of Mr. Weston's report and shall only mention here: (1) That the bacterial efficiency of mechanical filters depends very largely upon the use of a coagulant. (2) That a heavy dose of the coagulant when the filter is first started after washing hastens the formation of the film of hydrate of alumina on the surface of the filtering material, upon which the success of the process is said to depend very largely. (3) That the filtrate should be wasted for some minutes (fixed by Mr. Weston as 30) after newly starting a filter, owing to the poorer results then obtained, and the possible risk from alum carried through the filter during the heavy dosing. (4) That only during the first few minutes of the run of the filter could any alum in solution be found at Providence, and this in minute quantities. This is a very important conclusion, as the opponents of mechanical filtration have laid great stress upon the danger from using alum as a coagulant. Comparatively small quantities were used at Providence, and these were regulated with great care. The results on this point indicate that as mechanical filters have heretofore been operated, some alum may have got into the filtrate, especially just after washing, where the filtrate is wasted only until it runs clear, as is generally the case, and when large quantities of alum are being used. (5) The comparatively short average run at Providence, where the water was generally clear, indicates that the frequency of washing, under some conditions, coupled with the wasting of the filtrate for a half hour afterwards, would make the total amount of water wasted very high in some cases. Mr. Weston gives this figure for Providence as 7.8% of the total quantity filtered during the run. If washing was done with filtered water, even this quantity would be an important factor, and when it was materially exceeded the percentage of wasted water might become a serious matter. Mr. Weston first based his estimates on washing with filtered water, but afterwards changed to unfiltered, materially reducing thereby his estimate of the cost of operation. Whether washing with unfiltered water would be advisable under all or any circumstances we cannot discuss now, Mr. Weston appears to think it would be safe for Providence.

The proposed increase in the number of engineer officers in our navy is being made the subject of various bills now before Congress, varying in their provisions as they advocate the opposing interests of the line or staff corps of the navy. In connection with this question a correspondent of the St. Paul "Pioneer-Press" abstracts very substantial reasons for an increase from the latest naval registers of England and the United States. He presents an elaborate table of ships of comparable types in the two navies, classed by displacement, steam power and number of line and engineer officers on each. From this table he shows that there are 25 per cent. more engineers on the English than on the American warships, and that while each one of our engineers has an average of 2,360 I. HP. under his charge, the English engineer has only 1,825 I. HP. to look after. The same table shows an excess of 25 per cent. of American line officers on these ships as compared with the British organization, or one line officer to each 384 tons of displacement of the American ships to one line officer for 528 tons on the English ships. The entire English navy contains 850 engineers to 1,760 line officers—a ratio of about 1 to 2. The American list shows 192 engineers to 718 line officers—a ratio of nearly 1 to 4. In this connection, however, the correspondent above referred to fails to point out the much lower pay of the English engineers, as compared with our own, and the friction and prejudice, almost equal to that between our own line and staff, existing in the British navy. But on the basis of numbers alone, combined with the fact that in March, 1895, 233 more engineers than were available were needed in the British navy, this tabular exhibit further shows the necessity of a speedy increase in the number of our engineer officers. To quote from a late editorial in the London "Engineer": "The naval supremacy of Great Britain rests in the hands of the engineers," and "without the engineer, the admiral, the bluejacket, the whole executive branch of the service are useless." The same remarks apply equally well to our own service, and their true import cannot too soon be recognized by Congress, regardless of the wishes or interests of an opposing and prejudiced class of officers.

The last bill presented to Congress, in this connection, is a very ill-advised and foolish measure; one opposed to all modern ideas of progress and calculated to do much mischief. This bill proposes to still further reduce the staff of highly educated and technically trained engineer officers, by placing but one officer of this grade upon each ship under 2,000 tons displacement, and two such officers only on larger vessels. It would replace the engineer officers of lower grade with "skilled mechanics," rated as warrant officers and receiving from $40 to $70 per month. The economy of this measure is not apparent, and the assumption that these warrant officers can equally well perform duties now intrusted to scientifically educated men, is a false one. The machinery of a modern warship is a very costly affair, upon that of the cruiser "Minneapolis," for example, $1,300,000 is said to have been expended. To keep this machinery in a constant state of efficiency and to operate it with the best economy requires more intelligence, skill and scientific training than can be anywhere obtained for the paltry pay set down in this bill. Ignorance in the manipulation of valves or in the handling of boilers may mean more waste in the consumption of fuel per horse power, in a few weeks' steaming, than the equivalent of the annual pay of the most highly trained officer. From an economical point of view alone, this government cannot afford to place its million-dollar engines in the sole care of a seventy-dollar man.

But aside from all questions of economy, there is another question of discipline in the engine room that must be considered. Under modern conditions the general engineering staff of a warship is a large and varied one, with many important duties to perform. In battle this staff will all be below deck, exposed to terrific heat, to dangers from bursting steam pipes and to all manner of seen and unseen dangers. To keep full control over this body of men under these conditions, and to quickly and properly meet all emergencies requires an amount of nerve, intelligence, training and power that a commissioned officer of relatively high rank alone can possess. To say that a warrant officer, one remove above the enlisted man, can perform all these duties and compel this obedience to orders, is to admit that the ship's gunner can take general charge of the deck quite as efficiently as the Captain himself. Authority and ability to command belong to rank alone, and executive ability and power to command are quite as much needed below deck as above deck in the handling of a modern warship.

It is now proposed to entirely remodel and rebuild our Naval Academy, and when this is done it would seem well to entirely separate the education of line and staff officers. The course of training is essentially different, and each branch should be under the control from the beginning, of officers of its own grade. With provisions made for admitting students of our technical schools to post-graduate courses, on the general lines laid down by Commodore Melville, several good ends would be served. The naval engineer cadet would be entirely removed from the deep-rooted but silly prejudice against his class, now powerful for evil at the Academy; the method of selection for the engineer school would be such as to secure the students best fitted for this service and to eliminate those lacking in proper qualifications. The complete four years special course should turn out men best fitted to design, maintain and operate the costly ships of our new navy. When the engineer graduates do finally meet the line graduates in service, it would be upon a basis of equal previous opportunities and school prestige, and with a relatively higher scientific education. Both would be "gentlemen" in the only recognized sense of that term; and it should not take long for the prejudice, that belongs to another time and very different conditions, to die out altogether. Experience teaches that the present Naval Academy system of common education for the first two years is bad in inculcating the prejudice that seems to last through a life service. It is time to change this system, not only for the benefit of individual officers, but for the greater efficiency of our entire naval service.

In the description of the cycle track at El Paso, Tex., in our department "Letters to the Editor" last week, some errors occurred through delay in the receipt of the corrected proof from the author The last half of the first paragraph of the letter should read as follows:

The amount of banking from A to A was determined by the following formula: $\frac{W \times V^2}{32.2 \times R}$ = tangent of the inclination of the rider from the vertical when riding the curves. This formula also gives, of course, the tangent of the inclination of the surface of track from the horizontal necessary to bring said surface perpendicular to the inclination of the rider. In the formula, W is always equal to unity or 1. For the El Paso track I assumed the velocity V equal to 40 ft. per second and supposed the rider to be 11.5 ft. from the "pole," which made R, the radius, equal to 180 ft. This gives $\frac{1 \times 40^2}{32.2 \times 180} = 0.24+$ or practically an inclination of 1 in 4.

THE EFFICIENCY OF MODERN FIREPROOF BUILDING CONSTRUCTION.

The efficiency of the common systems of fireproofing as a protection against the serious damage and destruction of buildings from fire is a question which is just now receiving considerable attention from insurance companies and other interests concerned in fire risks and danger from fires in modern office and mercantile buildings. This agitation appears to be due in a large measure to the disastrous fire which occurred in the Manhattan Savings Bank Building in New York city Nov. 5, 1895 (Eng. News, Nov. 14, 1895), and to the rather sensational assertions made shortly thereafter by Mr. Bonner, Chief of the New York Fire Department. Mr. Bonner then made the following statement:

I am prepared to declare from my experience that a building of brick and yellow pine in case of fire is easier to manage and the contents have more chance of being saved than in the modern fireproof building.

In a newspaper interview, Chief Marshal D. J.

Swenie, of the Chicago Fire Department, is quoted as saying: "No style of construction and no building material that has ever come under my observation will render fireproof a building filled with inflammable goods. I think very much as Mr. Bonner does."

In a recent paper, Gen. Wm. Sooy Smith, M. Am. Soc. C. E., of Chicago, who has made a careful study of building construction, says:

> I know of no fireproofing that has yet been used to protect the steel in composite buildings that has proved effective when exposed to fire.

On another page of this issue we bring to a conclusion an article by a well-known Chicago contractor for fireproofing, which summarizes a number of disastrous experiences with fires in fireproof buildings in a very instructive manner.

To many engineers who have studied the subject of fireproofing, the above statements will not come as entire strangers, but they will be received with surprise, we think, by the public in general. Whatever one's preconceived ideas may be, however, it cannot be doubted that, when coming from such authorities, they are statements worthy of serious consideration. Are architects and engineers, as Mr. Bonner says, "leaning on broken staves" in their too-firm belief in the efficiency of modern fireproofing? This question is one which cannot be passed over lightly, for its close relation to great life and property risks demand for it serious consideration. We may, therefore, profitably take a little time to study some of its features here. The questions to be considered are: What evidence is there tending to show fault or inefficiency in present systems of fireprof construction? In what direction is improvement possible?

Fireproof is a relative term; no material furnished by nature or developed from the products of nature by any artificial treatment known to man is proof against destruction by fire under certain conditions. It is evident, then, that by a fireproof material is meant in the broadest sense one which is less readily damaged by fire than any other. In building construction the meaning is much more limited. Here a fireproof material means the material least affected by fire which can be used in building construction under the ruling conditions of strength, lightness, adaptability, cost, etc., which govern such constructions. Protection against fire by the "fireproofness"—to coin a word—of any available building material is therefore only partial at the best. The truth of the preceding assertions is almost axiomatic, but we not infrequently find an entire misconception of it.

The application of the above truths will be evident later; but one or two questions of a more general nature may be taken up beforehand. First, it is essential to know the manner in which fire acts to destroy building materials. Its first effect is, of course, to burn the combustible material; its second effect is to generate local or general strains in the incombustible material through the expansion caused in all substances by a rise in temperature; and its third effect is to change in a greater or less degree the physical or chemical nature of certain of the non-combustible materials by rendering them flexible or brittle or by destroying their cohesive or adhesive qualities. These are all well-recognized effects of heat and need not be amplified further. One thing should be noted here, however, and this is that the introduction of conditions inimical to fire may increase the damage from it; for example, the water used in extinguishing fires, by its sudden cooling of heated materials may cause them to contract, twist, crack or fly into pieces, and thus cause more damage to those materials than the fire alone would have caused. This point will be referred to again by concrete examples, but its general bearing here will be easily seen; fire damages under the present condition of affairs include damages from fighting fire as well as damages from fire or heat proper.

Having the foregoing basis of facts to work from, the general manner in which fire acts to destroy modern building constructions can be analyzed when the character of the construction is known. If we except buildings of a purely monumental character, practically all fireproof buildings to-day consist of a more or less extensive framework of iron or steel, partly or wholly covered with an integument of stone, brick, tile, plaster, etc., which incloses the framework and protects it from extraneous agencies to a greater or less degree. Attached to the tile, brick, etc., is a combustible finish of very small volume as compared with the volume of non-combustible materials. This combustible finish, together with the contents—merchandise, furnishings, etc.—of the building, forms the fuel from which the heat tending to destroy the structure in case of fire is developed.

In a fireproof building fire, therefore, the heat developed by the burning of the combustible material acts first on the enveloping integument covering the framework. It may cause this covering to crack or crumble if the heat is sufficiently intense or water is introduced, but in any case it sooner or later penetrates to the adjacent steel member and causes it to expand. According to the intensity of the heat and the manner in which it is applied this expansion may be local and unimportant or it may be intense enough to wrench the columns out of plumb, twist the connections, tear off the fireproofing and finally overthrow the building wholly or in part. Now, it stands to reason that if the heat, though finally of great intensity, reaches the steel work gradually, its effect will be less injurious than if it reaches it in a sudden concentrated blast. The same thing is true of the contrary action of sudden cooling. The reason for this is that sudden heating or cooling means in such a case uneven heating and cooling or uneven contraction and expansion—i. e., warping and twisting.

This theoretical action of heat on a fireproof building construction does not depend alone for credence upon its evident accuracy of reasoning from cause to effect, but is proved by actual fire records. Take, for example the Manhattan Savings Bank, which, while far from representing the best fireproof construction, would ordinarily be called fireproof by builders, landlords and the public generally, and which, indeed, was actually as well fireproofed in its effective resistance to a really severe fire as buildings, samples of which are often seen, with the lower floor beam flange covered with a ⅝-in. tile or a coat of plaster. Note what occurred when this building was burned. Fire Marshal Bonner, of New York, says:

> The heat from the Keep Building on the opposite side of the street acted directly upon the exposed ironwork of the Manhattan Building. The iron resisted the heat, that is it did not blaze, but so far as the safety of the building was concerned it did something infinitely worse. It expanded under the heat and forced the ends of the beams and girders from their resting places on the supporting piers. The result was inevitable, the floors came down and brought with them the mass of fire brick used as flooring, the floor columns and finally the roof.

The same thing was taught in a less destructive manner by the Schiller Building, Chicago Athletic Club, Temple Court and other fires. Note particularly in the Athletic Club Building the expenditure of $8,400 in replacing twisted beams and columns (Eng. News, April 9, 1896) in a merely skin-deep fire. Notice also in all cases the damage not only to the plastering, but to the structural fireproofing as distinguished from the surfacing—i. e., the cracked and broken tiles opening way for the direct passage of flame to the steel work and to the adjacent rooms.

This last point deserves a little further mention. The rupture of the fireproofing, besides laying the steel immediately adjacent bare to the flame, is of more moment in that it affords fresh opportunities for destructive action by admitting the fire to another room. This is a fundamental defect, for the basic principle of fireproofing is confinement of fire, the reduction of opportunity for the spreading of flame and heat. The purpose of fireproofing is to confine fire in locality and intensity sufficiently to prevent extensive damage until it can be extinguished by methods in common use. This object is accomplished by reducing the amount of combustibles and by construction designed to keep the incipient fire isolated and harmless—i. e., to prevent it from enlarging to an injurious degree until means for extinguishing it can be had. There is a limit, generally a pretty high one, beyond which the amount of combustible material cannot be easily reduced, so we have to turn to the other safeguard. The extent to which this can be secured depends upon the use of the building (the most favorable condition of use is found in the big office building, with its many separate rooms; and the least favorable, perhaps, in large department stores), and also upon the ability of the barriers or partitions to remain intact under the action of fire and water.

Fire records, as well as reason, teach that the steel skeleton of a modern office or mercantile building is far from being a rigid thing under heat; but that it is a creeping, drawing, twisting thing, striving to tear off its protecting clothing and disrupt its members with every intense change of temperature. Fire records also show that in modern systems of fireproofing the greatest danger of heat reaching the steel work or spreading to adjacent rooms lies in the cracking and breaking down of the protecting covering or partitions. Experiments and fire records show that the disruption of protecting materials is due mostly to the direct action of flame and the water used in extinguishing flame—i. e., to sudden intense contractions and expansions.

Summarizing briefly, then, we may conclude: (1) The most serious danger to the integrity of a building by fire lies in the distortion of the steel frame by heat; (2) the most dangerous defect for a fireproofing is easy disruption by fire and water, thus leaving the framework partially bare and exposed to the direct action of the flames and affording openings for the spread of the fire; (3) fire records show disruption under fire and water to be the most noticeable defect of the fireproofing materials commonly used to-day.

To appreciate the significance of these facts in the problem of improving the present methods of fireproofing, the characteristics of a theoretically perfect protective covering against heat must be studied a moment. To protect from heat perfectly a covering must not conduct heat in dangerous intensities, it must not afford loose joints for the passage of flame and hot air, and it must not fall away, crumble or fly into pieces under sudden and intense changes of temperature (the attack of fire and water). These are the qualifications of a perfect protection against heat, and they are not possible of full attainment in the practical work of fireproofing buildings. It is evident, however, that the conductivity and the existence of loose joints are possible of pretty complete remedy within limits with any material. If a material bursts into pieces under the attack of heat and water, however, no such easy remedy is available. About the only thing that can be done is to use it in a form where its disruption entails the least deep-seated damage and danger.

Economy suggests that such a construction must assume the form of a protecting armor or surfacing, whose duty it is to keep the flame and water from the more vital structural parts, and whose destruction is the preservation of the vital parts. Take, for example, a tile arch floor or a tile wall, where the tile has a constructive office—i. e., where the tile forms the floor or wall—if the tile cracks or breaks, a structural damage to the building results. On the other hand, protect this wall or floor by a surfacing which keeps the flame and water from it, so that it does not crack and break, and the damage is limited to the construction of a new armor. It is a surface and not a structural damage. This point is well illustrated by the figures of cost for repairing damages by the Athletic Club fire. Notice the vast amount of money expended in renewing floor arches and partitions—i. e., structural features for the purpose of repairing surface damage.

The foregoing must not be misinterpreted. A sufficiently intense heat will destroy any system of fireproofing. All that is urged is that for equal intensities of heat very much less damage results with a surfacing to take the attack of flame and water than without one. When a constructive material is found which will withstand intense and uneven heat and the direct attack of water without cracking or being destroyed this may cease to be true, but no constructive fireproofing which is commonly used to-day is indisputably admitted to withstand these conditions except brick, which are of limited availability for interior fireproofing. On the contrary, there are surfacings which are admitted to withstand quite well the attack of flame and water, but which must have a backing of constructive material to support them.

No doubt there will be many who will dispute the desirability of combining a surfacing to resist flame and water with a body of less resistant material on account of the extra cost or because it is considered that the structural body is unnecessary. First as to cost, it is a manifest economic truth that it is not wise to spend large sums to resist the fire that occurs with extreme rarity, but this is not the reason why the extra surfacing is urged here. The constructive fireproofings ordinarily used do not resist ordinary fires without damage great enough to more than pay for the cost of the protective surfacing and its renewal after a fire. If it is economical at all in any particular case to go to the expense of fireproof construction, as distinguished from incombustible construction, it is economical to add the protective surfacing. In respect to the necessity of a fireproof backing, it is hardly ever disputed, even by those who advocate the use of surfacing alone, that a more resistant fireproofing is secured by the addition of a backing. It therefore becomes necessary for them to show that the extra cost of the backing is greater than the extra protection gained by its use, and this we do not think has been done.

The conclusions which may be drawn from the preceding discussion and the record of fires which suggested it we think are as follows: (1) Fireproof construction as distinguished from incombustible construction is necessary if the integrity of a building is to be preserved in even very ordinary fires. (2) The usual methods of fireproofing by the materials of construction are defective, from the fact that the protecting value of most materials so used is destroyed by their rupture when heated and subjected to the attack of water. (3) The most promising line of improvement is the use of a covering of material not easily damaged by the combined attack of heat and water to protect the more sensative constructive fireproofing from such attack.

In the foregoing paragraphs, fireproofing—that is, the structural nature of fireproof partitions and coverings—has been discussed with the idea of showing present structural defects and evolving a method of remedying them. Attention will now be turned to the broader question of protective construction against fire. There are two methods of reaching toward perfection here: (1) Reduce the combustible material available to start and to feed fire, and (2) restrict the possible area of action of a fire when once started. Incidental mention has been made of these rules farther back and in another connection. In practical building construction the designer is limited to the last method, or to restricting the area of action of a fire by partitions, for combustible merchandise and furnishings cannot be done away with. Most buildings are made to hold such materials and none are useful without they contain them to some extent.

Accepting these conditions ,the best provision possible has to be made against two classes of fires—viz., exposure fires from the burning of adjacent buildings and interior fires, starting and burning inside the building itself. Protections against exposure fires should look chiefly toward preventing the generation of interior fires by radiated heat and flame. This means impervious outer walls. Protective construction against interior fires should be toward the end of preventing the rapid spread of fire. This means frequent impervious partitions, enclosed elevator shafts and stairways and the general abolishing of all passages for the free travel of flame from one part of the building to another.

It is obvious that these requirements are not possible of perfect attainment in our office and mercantile buildings, for the outer walls must have windows, the inner partitions must have doors and there must be hallways, stairways and shafts which cannot be entirely enclosed. The best that can be done is to minimize the number and size of the outer windows and protect them by incombustible shutters; to avoid large rooms by introducing frequent dividing walls; to minimize the number and size of the doors and windows in these interior partitions; to enclose the shafts and stairways to as great an extent as possible. These are all protective constructions and it is evident that the possibility and extent of their application depends upon the character and purpose of the building. Like all protective constructions, moreover, they are simply devices for delaying the damaging spread of fire until it can be extinguished, and logically demand supplementary protective constructions in the shape of stand-pipes and fire hose, automatic sprinklers, ready means of access for firemen and shelters from which they may fight fires.

There are no new ideas in the preceding three paragraphs, but they are all ideas which we seem to be forgetting, with the increasing use of steel and fireclay in place of wooden joists and beams. In this place and in the article on another page the attempt has been made to show wherein our steel and tile construction is weak, and how its defects may be corrected. Some of the conclusions may be disputed, but the facts stand that in every fire of any size recorded in a fireproof building, the building was found vulnerable to the flames; the constructive tiling cracked and broke, the adjacent metal framework was injured, the flames spread by means of doors and stairways and broken tile partitions. The results were the same in the exposure fire at the Schiller Building and the interior fire at Temple Court. Undisputably the fireproofing of tile did great good in both cases, as a non-fireproof building would probably have been destroyed under the same conditions, but it did not prove efficient enough to warrant neglect of the old protective constructions which are being thrown aside in this new era of steel and tile.

That the whole question of fireproofing and protective construction against fire is an economic one in its practical workings has been realized in the foregoing discussion. Some of these questions of economy are discussed elsewhere in this issue and the preceding issue, but we have been chiefly concerned here to indicate wherein our best building construction falls, and how it may be improved in respect to its resistance to damage and destruction from fire.

LETTERS TO THE EDITOR.

The Destruction of the Niagara Suspension Bridge.

Sir: On further investigation respecting the matter discussed in your issue of Feb. 13, p. 106, I find that my account of the injury done to the upper suspension bridge, at Niagara Falls, by the gale of 1869, and Mr. Dunlap's account of its destruction by the great gale of 1889 are both correct. I was not a resident at Niagara in 1889, and the destruction of the bridge, having been noticed only in the newspapers, escaped my observation.

Ithaca, N. Y., April 10, 1896. G. W. Holley.

Concerning the Diagram of Mountain Railways of the World.

Sir: It would have been more accurate if the maker of the diagram which you copied from the "Zeitschrift der Oesterreischen Ingenieur und Architekten Vereines," had written Santiago, instead of Valparaiso, on the Transandine Railway in Chili, and Arequipa instead of Mollendo, on the South Peruvian Railway. The two cities named on the profile are seaports, and not on the mountain slope as shown. The Galera tunnel is nearly two meters higher than stated. Jas. R. Maxwell.

Newark, N. J., April 11, 1896.

New York Civil Service Examinations.

Sir: The New York City Civil Service Board will hold examinations as follows: Inspectors of Meters and Water Consumption, on April 23, at 10 a. m.; Plumbing Inspector, on April 20, at 10 a. m.; Engineer-Inspector of Regulating, Paving and Grading, on April 22, at 10 a. m.

These examinations consist of writing, arithmetic, technical knowledge and experience. Citizens of the United States are eligible to these examinations. For the last position, it is required that applicants be well informed on engineering subjects. Applications may be obtained by addressing the undersigned. S. William Briscoe,

Secy. N. Y. City Civil Service Board.

New Criminal Court Building, New York City, April 10, 1896.

The Montreal Bridge Competition.

Sir: Quite a number of engineers are asking themselves if the invitations sent out nearly a year ago by the Montreal Bridge Co. for designs to be submitted for the proposed St. Lawrence bridge were made in good faith. If the dealings of the bridge company are above board, why is nothing heard from them? Can you throw any light on the subject? Respectfully,

March 6, 1896. Query.

(We sent a proof of the above letter to the Montreal Bridge Co. with an invitation to reply, and after some time, as we received no answer, we repeated our request. As we still failed to receive any reply, we deem it best to publish the letter without further delay.—Ed.)

The Danger of Square Cast-Iron Columns.

Sir: An interesting and vital point, as to "Safe Loads on Cast-iron Columns," is not touched upon in the correspondence of Messrs. Sodermann and Levering & Garrigues, in your issue of April 2.

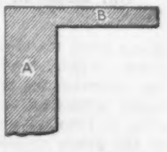
I do not propose to go into the niceties of formulas for the strength of round columns; but I would call attention to the fact that square columns of cast iron are now recognized as a proper form or method of construction, and tables are given showing their safe loads. These tables even tell us that their safe load is from 30 to 45% greater than for round columns of a corresponding size and thickness.

The fact that the use of these square columns is again permitted in New York is a surprise to me. You ask the question, editorially—"Is cast iron stronger in Boston than in Chicago by some 10 per cent. and stronger still in New York?" But it seems to me that the advisability of using square cast-iron columns at all for important work, is a much more important question. The real objection to the square column of this type is that it is exceptionally liable, from its shape and manner of manufacture, to be strained, almost if not quite to the point of destruction, by unequal contraction in cooling. Round columns of cast iron are not subjected to this risk to nearly the same extent.

A very good example of the existence and extent of these strains in castings is found in your issue of March 26, p. 216. With a very small difference in the thickness of metal on the two sides of a right angle, a piece 51 ins. in length springs off 2¼ ins. at the center, showing a difference in length of about one-quarter inch in 51 ins.; a surprisingly great difference in the contraction of the metal on the two sides of the angle, under conditions which would not be expected to produce so great a difference.

Even with the grades of iron best suited to the requirements of building construction, one side of the rectangular box, forming the square column, is almost sure to cool much more rapidly than the other, after casting; and by thereby becoming shorter in length than its adjoining side a strain is brought upon one or both of the corners which join it to its neighbors.

The accidents of unequal cooling may originate in the manner or speed of pouring, in the state of any part of the mold, or from the casting being uncovered unequally and thereby exposed in parts to the cooling effect of the air. If in connection with these accidents there be any inequalities in the thickness of the four sides of the column, it is well known that the thick side will retain enough heat to make it continue to contract in length long after its thin neighbor has attained the length it will hold to the end of its history. As shown in the accompanying illustration of the angle of a square column, the thick side will continue to contract long after B has "set," and the amount of difference in the contraction of the two parts can easily be nearly 1-16 in. in 1 ft. of length, as in the case of the mullion referred to. It is apt to be much greater.



In a column 16 ft. long this difference would be 1 in., sufficient to put such a strain upon the structure as to make its use extremely hazardous, especially under the "safe loads" permitted by the tables given by your correspondent.

The failure of a square column of large size, some years ago, led apparently to their disuse for a long period; but this lesson seems to be now forgotten. If the reason for this return to old practices is as you say—"that the New York law was framed with a tender regard for the interests of the foundry men," would it not be better for the said foundry men to have the law amended so that all cast-iron columns shall be round in section instead of square? The round column has no angles, and it is impossible for contraction to ruin it, or to impair its usefulness to any great extent. To the best of my knowledge, no case of failure in a round column can be traced to this cause. The use of rectangular cast-iron columns is bad practice, both from the founder's and from the builder's point of view, and unless this practice is stopped disaster will surely some time follow. John F. Ward.

45 Broadway, New York City, April 10, 1896.

Notes and Queries.

M. T. D. wishes to know what quantity of water is meant by a miner's inch in Pennsylvania, and whether this quantity is defined by statute or simply by common consent among mining companies.

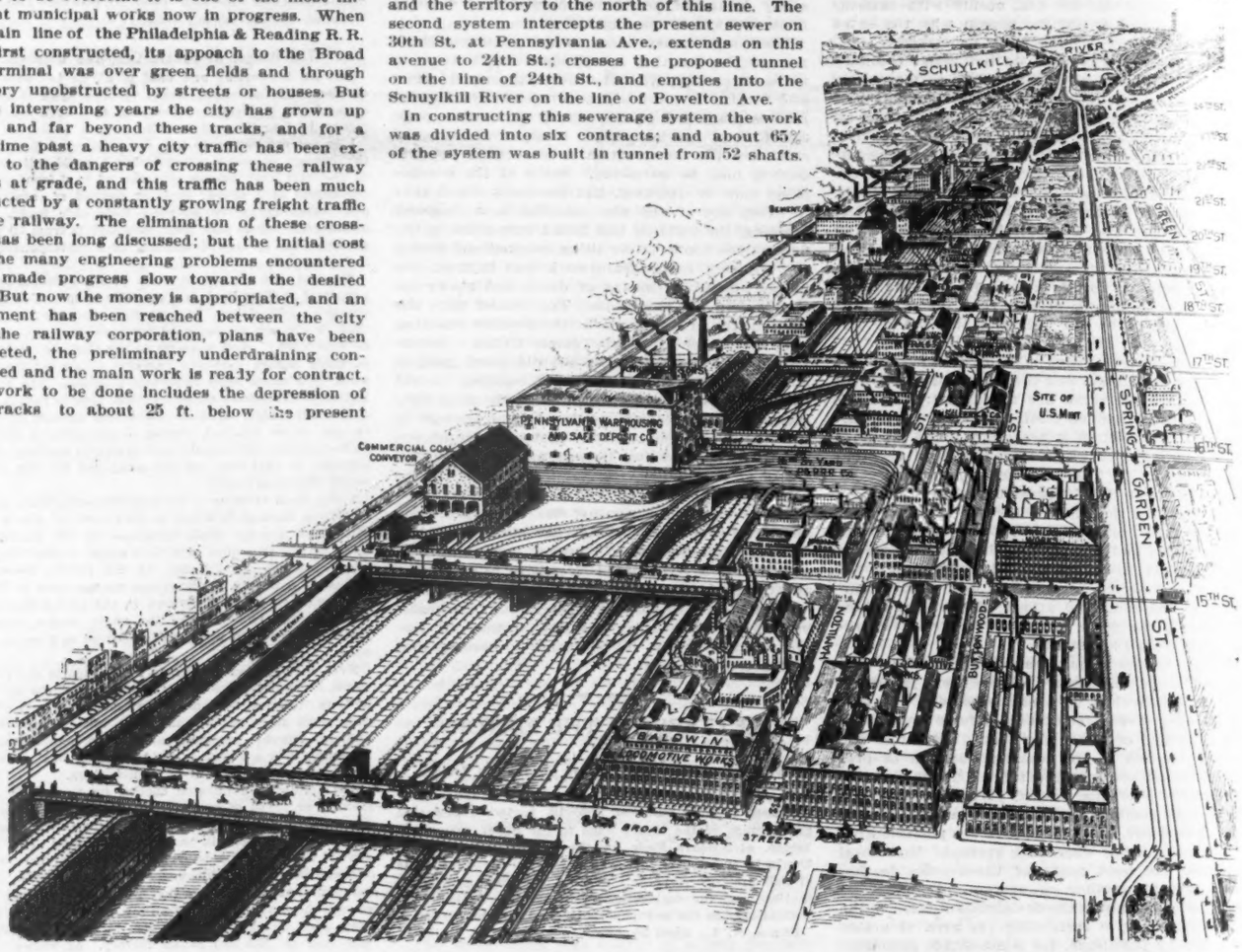
THE PENNSYLVANIA AVENUE SUBWAY AND TUNNEL IN PHILADELPHIA, PA.

The removal of seventeen dangerous grade crossings in the heart of Philadelphia is the incentive for a most interesting piece of engineering work in that city; and in magnitude and difficulties to be overcome it is one of the most important municipal works now in progress. When the main line of the Philadelphia & Reading R. R. was first constructed, its appoach to the Broad St. terminal was over green fields and through territory unobstructed by streets or houses. But in the intervening years the city has grown up about and far beyond these tracks, and for a long time past a heavy city traffic has been exposed to the dangers of crossing these railway tracks at grade, and this traffic has been much obstructed by a constantly growing freight traffic on the railway. The elimination of these crossings has been long discussed; but the initial cost and the many engineering problems encountered have made progress slow towards the desired end. But now the money is appropriated, and an agreement has been reached between the city and the railway corporation, plans have been completed, the preliminary underdraining constructed and the main work is ready for contract. The work to be done includes the depression of the tracks to about 25 ft. below the present street level, the creation of a freight yard, engine-house, repair shops, etc., in this depression, and the maintenance of railway connection with the many industrial establishments located on both sides of Pennsylvania Ave. Aside from the relief at the grade crossings, the business of the railway company will be much facilitated by this improvement, and the main entrance to Fairmount Park will be greatly improved.

As the old sewers were not deep enough to drain the depression to be made, and as they would be necessarily cut in making the excavations, one of the first things to be done was to plan and construct an entirely new drainage system.

This work has now been completed, and embraces 3½ miles of sewers, placed from 20 to 40 ft. below the street surface, and varying in size from 12-in. terra-cotta pipe to a diameter of 10 ft. 6 ins. One of the main systems begins at 13th and Buttonwood Sts., passes south to Callowhill, thence on Callowhill to 23d St., and thence over Powelton Ave., 24th and Wood Sts. to the Schuylkill River. This system acts as an interceptor for the sewers on the cross streets, and drains the roadway of the depressed subway and the territory to the north of this line. The second system intercepts the present sewer on 30th St. at Pennsylvania Ave., extends on this avenue to 24th St.; crosses the proposed tunnel on the line of 24th St., and empties into the Schuylkill River on the line of Powelton Ave.

In constructing this sewerage system the work was divided into six contracts; and about 65% of the system was built in tunnel from 52 shafts.

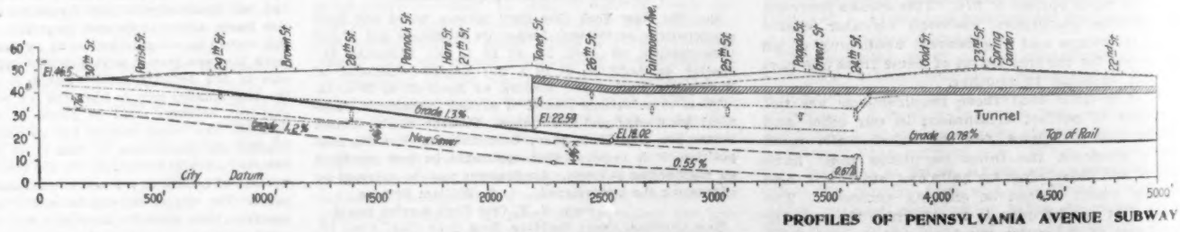


THE REMOVAL OF GRADE CROSSINGS ON THE PHILADELPHIA & READING R. R. IN PHILADELPHIA. GENERAL BIRDS-EYE VIEW OF PENNSYLVANIA AVENUE SUBWAY AND TUNNEL.

The work was attended with great difficulties, as the flow of existing sewers had to be maintained, and much blasting was done in close proximity to industrial establishments containing delicate machinery. Quicksands were met with, and in passing through old wharves, near the outlets, the tide had to be fought. These difficulties were all successfully met, however, and all is now in readiness for commencing upon the main construction of the depressed track.

As planned, there is but a slight change in grade at 12th St., the street passing beneath the track. At 13th St., the track maintains about the present level of the street, while the street itself is carried beneath the track; but between 13th and 16th Sts., and from the north side of Pennsylvania Ave. to the north side of Callowhill St., the whole area is to be excavated to form a depressed freight yard for the Philadelphia & Reading R. R., as shown on the accompanying bird's-eye view. Broad St. and 15th St. are to be carried across this depression on bridges, and by slightly raising the level of the streets. The extensive Baldwin Locomotive Works and the large warehouse at 16th St. will be reached by inclined planes, with 5% grades, operated by ordinary locomotives. To connect the depressed tracks with the works of Messrs. William Sellers & Co. and A. Whitney & Sons, a hydraulic lift will be used, located on the south side of Pennsylvania Ave. near 17th St. This lift will be capable of raising a locomotive and three loaded cars at one time. The Baldwin Locomotive Works, between 17th and 18th Sts., the Philadelphia Grain Elevator and the plant of the Knickerbocker Ice Co., will be connected with the subway by inclined planes of 4 and 5% grades, operated by ordinary locomotives. Connection will be also made with the works of Bement, Miles & Co. by a similar plane, and the triangular piece of ground now occupied by the Philadelphia & Reading R. R., at 20th and Hamilton Sts., will be excavated, and will contain the new engine-house, freight-house and repair shops.

The tunnel begins just east of 22d St., and will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be a single brick arch of 52 ft. span and 8 ft. 8 ins. rise, designed to contain four tracks. The tunnel will extend approximately to the entrance of the present Baltimore & Ohio tunnel, west of 26th St. Owing to this tunnel, Pennsylvania Ave. will be widened from 22d St. to Fairmount Ave., and after the completion of the tunnel the space over it will be paved and provided with grass plots, so as to make a handsome entrance to the Park. West of the line of the Baltimore & Ohio tunnel entrance, the tracks will be carried, in a gradually ascending open subway, to the present level of the tracks at 30th St. The many engineering problems to be encountered include the underpinning and support of a number of large buildings, warehouses and elevators, while the work of excavation is in progress, and the blasting of rock in close proximity to these structures. All of the present gas and water mains and electrical conduits must be maintained during construction and later either carried on the bridges or beneath the subway. Railway connection must also be kept up with the various industrial establishments and the temporary freight yards of the railway company. The ordinance of the City Council, of March 17, 1894, authorizing the work, appropriates the sum of $6,000,000 for construction, and of this sum the Philadelphia & Reading Ry. Co. is to pay $3,000,000. The plans have been prepared by the Department of Public Works and Mr. Joseph M. Wilson, M. Am. Soc. C. E., acting as consulting engineer for the Philadelphia & Reading R. R. Co., and they include 600 general and detailed drawings. The city officials in charge are Mr. Thomas M. Thompson, Director of the Department of Public Works, and Mr. George S. Webster, M. Am. Soc. C. E., Chief Engineer of the Bureau of Surveys, who will have immediate charge. The other engineers in charge of the work are Messrs. George E. Datesman, Samuel Tobias Wagner and R. I. D. Ashbridge, and Mr. Charles H. Swan is the chief draftsman. The work has been divided into 26 contracts, and the bids for the construction will be received until May 12.

Owing to the heavy traffic provided for, and the very large dimensions of the tunnel, a complete system of artificial ventilation has been provided, with side exhaust conduits, fresh air intakes and two fan stations. This is an exceedingly interesting feature of the tunnel construction, and the accompanying plans show, in a general manner, what is contemplated. On the north side of the tunnel will be two fan stations dividing the tunnel into four almost equal sections. At each station will be two 20-ft. fans drawing out the foul air and gases from the tunnel through openings provided at intervals of about 150 ft. These openings lead from the roof of the tunnel to a conduit, located parallel to the north side of the tunnel and of varying diameter. The gradients in these conduits are so arranged that any water of condensation will run to the fan stations and be there taken care of. The conduits are 11 ft. in diameter at the fan stations and decrease to 6 ft. 6 ins. in diameter at the ends.

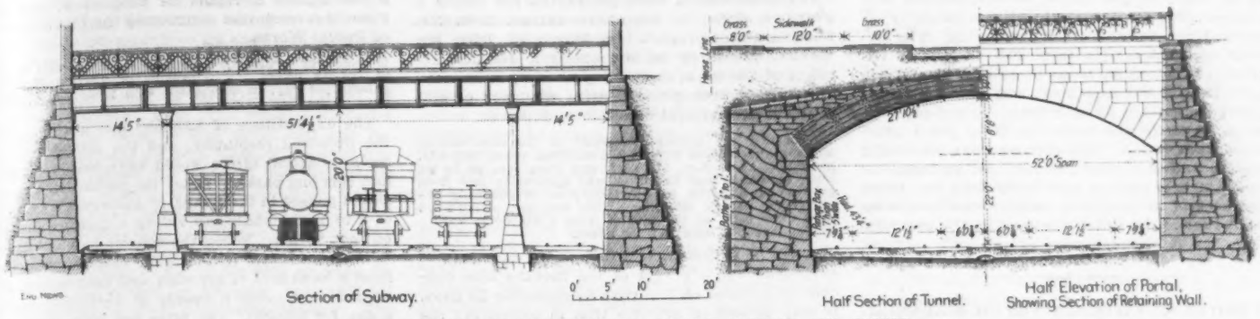
The general arrangement and design of the ventilating machinery is not yet completed; but it is proposed to drive these fans by electric motors and to discharge the gases into stacks high enough to prevent any inconvenience to surrounding properties. At the stations the conduits will be so arranged as to permit the fans being connected with either line of conduits, so that one fan can exhaust from both in case of breakdown or repairs. Each fan is figured to have a capacity of about 150,000 cu. ft. per minute, giving a combined capacity of 600,000 cu. ft. per minute, or about one-fifth of the entire cubic contents of the tunnel. It is expected that the air in the tunnel can thus be entirely renewed every 5 minutes.

On the south side of the tunnel will be the fresh-air intakes, each having a cross-section of 35 sq. ft. These intakes will connect with the interior of the tunnel at the level of the rails, and the street openings will be located in grass plots between the curb and the sidewalk. The intake openings are to be located midway between the exhaust openings.

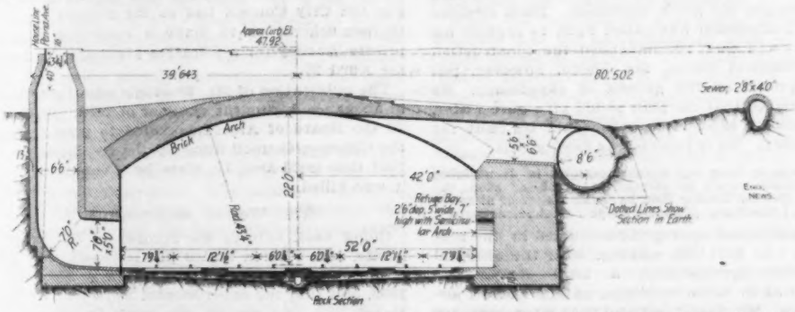
If there is any tendency for the gases to escape through the air intakes, a system of automatic shutters will be provided, which will close when the pressure of air is outward from the tunnel. A power house, located near 19th St., will furnish the power required to operate the fans and the hydraulic lifts before referred to.

While not shown on the plans here given, these depressed tracks connect eastward with the Philadelphia & Reading terminal station, at 12th and Market Sts., by means of an elevated structure. At 12th, as at 13th St. the streets are carried beneath the railway. The rise in the tracks begins at the bottom of the depressed subway, just west of Broad St, and ascends with gradients of 2.50% and 1.46%, until the level of the elevated road leading to the terminal station is reached.

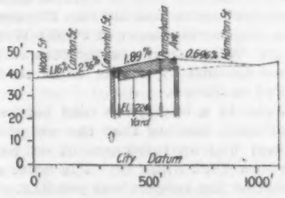
The following items of general interest are taken from the specifications: The approximate quantity of excavation is 351,000 cu. yds.; rubble

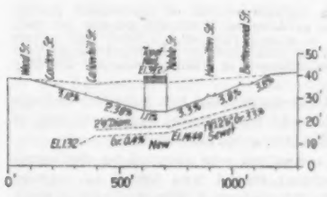


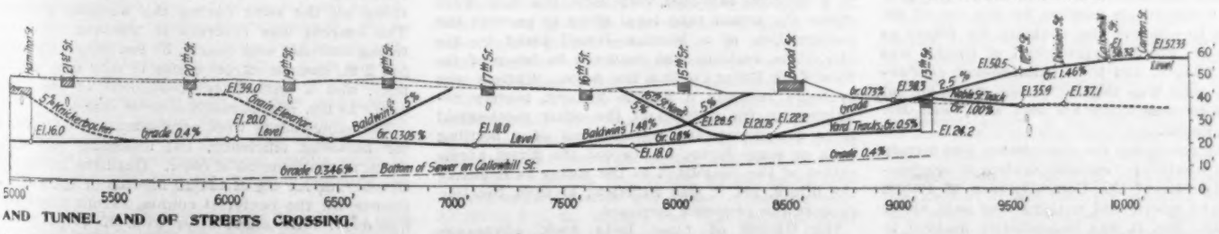
CROSS SECTIONS OF PENNSYLVANIA AVENUE SUBWAY AND TUNNEL.



Cross Section, Showing Arrangement for Ventilating Tunnel.







masonry, 84,500 cu. yds.; brick masonry, 24,100 cu. yds. The tunnel arch and the fresh-air intakes and foul-air conduits are to be built of brick, and the latter must be plastered on the inside with ¼ in. of Portland cement mortar, 1 cement to 2 parts sand, so as to make them perfectly air-tight and smooth. The contractor must maintain travel across the excavation by temporary bridges; he is responsible for all damage to public or private property, arising from injury to water or gas mains, sewers, electric conduits, etc., and for damage to private property resulting from failure of underpinning. The security required ranges from 10% to 50% of the amount of the contracts, as these may range from $5,000 to $250,000 and over, and the contractor or his sureties will be held liable for the good order or repair of the work for three years after date of completion. The specifications cover 212 sections, and are very minute. An unusual requirement is a section specifying that any coins or articles of antiquity or value found are to be turned over to the Chief Engineer as the property of the City of Philadelphia.

THE PROVIDENCE EXPERIMENTS ON THE MECHANICAL FILTRATION OF WATER.

Investigators of the subject of water purification have long regretted the lack of data regarding the efficiency of mechanical filtration, a lack emphasized by the abundance of information relating to the efficiency of sand filter beds. The Rhode Island State Board of Health* has just made public an important contribution to our knowledge of mechanical filtration in the shape of a report by Mr. Edmund B. Weston, M. Am. Soc. C. E., Assistant City Engineer in charge of the Providence Water Department. This report gives the results of experiments conducted by Mr. Weston in 1893-4. The report is addressed to Mr. J. Herbert Shedd, M. Am. Soc. C. E., City Engineer of Providence.

A Review of Filtration Schemes in Providence.

Before taking up Mr. Weston's report, it may be of interest to briefly tell the story of how near Providence has come to establishing a filtration system at several different times, and how the various schemes have fallen through.

In February, 1893, a committee of the City Council reported in favor of mechanical filtration of the city's water supply, and presented a resolution to the effect that such a system be installed under the direction of a special committee of the council. An objection was made to putting the matter in the hands of such a committee, and the resolution was amended and finally passed and approved, directing the Commissioner of Public Works to

> contract for a suitable system of mechanical gravity filters, capable of filtering 15,000,000 gallons per day, at a cost not to exceed $100,000, provided this system of filtration is recommended by the Superintendent of Health, the Commissioner of Public Works and the City Engineer.

The sum above-named did not include buildings nor pumps, for which additional appropriations of $30,000 and $50,000, respectively, were made.

Before the resolution was adopted by the council, City Engineer Shedd was asked to express his views. He favored sand filtration rather than mechanical, but preferred an intermediate process. By virtue of his position he was one of the three men to approve the contract for filters as noted above. The Superintendent of Health was Dr. C. V. Chapin, and the Commissioner of Public Works, who was thus curiously made one of the Board to pass upon his own acts, was Mr. Robert E. Smith.

Under the resolution the commission was merely to approve whatever "suitable system of mechanical gravity filters" the Commissioner of Public Works might select, and nothing was said about experiments. But it was immediately decided to make experiments, and to include other than the class of filters named in the resolution. In response to an invitation to filter manufacturers, the Morison-Jewell Filtration Co. furnished a gravity, and the New York Filter Co. a pressure mechanical filter. There were also erected two filters of Mr. Shedd's design, which were called natural filters, but which were not fairly comparable in design or operation to the sand filter beds to which that term is sometimes applied.

It seems to have been arranged that Mr. Shedd should take charge of the engineering and Mr. Chapin of the bacterial phases of the investigation, but Mr. Weston was largely responsible for all the work from the start, and finally had practically complete direction of it.

The experiments were protracted for nearly a year, as stated in the above extract from Mr. Shedd's annual report. On March 12, 1894, Mr. Weston presented to Mr. Shedd a detailed account of the work, expressing himself, in his conclusions, regarding the relative efficiency of mechanical and natural filtration as follows:

> I consider the average efficiency of the experimental Morison mechanical filter for removing water bacteria, from Oct. 17 to Nov. 11, 1893, and from Jan. 24 to 30, 1894, at which time the filter was apparently free from growths of bacteria, as satisfactory as is generally obtained by natural filtration, with the best constructed sand filter beds, at the rate of from 2,000,000 to 3,000,000 gallons per acre per 24 hours.

It will be noticed that although the experiments extended over a period of ten months this conclusion is based on two runs aggregating 33 days. It may be said in addition that in comparing the bacterial efficiency of mechanical and so-called natural filtration no use was made of the results obtained with the latter during these experiments.

About the middle of May, 1894, a report from the commission came up in the Board of Aldermen, recommending the adoption of Morison-Jewell filters, and an additional appropriation for the same. The board passed an order for a "suitable system of mechanical gravity filters." On June 4, the resolution came up in the Common Council and brought out much discussion. Each member of the commission was called upon to express his opinion, and each recommended the construction of mechanical filters. Mr. Shedd, however, put his approval on the ground of expediency. He was satisfied that the plan would give pure water, but thought sand filter beds could be built for less money. He is reported as having said:

> If I was to have my dictum to-night, in determining what system should be adopted, I should say adopt the natural system. Rather than have the matter of filtration delayed, I would say promptly adopt a mechanical system.

The additional appropriation named in the resolution was $151,000, making, with the $130,000 previously appropriated, a total of $281,000 which was to cover buildings, pumps and all accessories. Mr. Shedd believed that filter beds and accessories could be built for $250,000. The estimated cost of operating the mechanical filters was $90 a day, or $32,850 a year for an average daily consumption of 15,000,000 gallons. Mr. Shedd estimated the cost of operating sand filters at $24,000 a year. Mr. Weston, being called on, estimated the first cost of natural filters as double that for mechanical filters. The resolution directing the Commissioner of Public Works to contract for "mechanical gravity filters" passed the Common Council by a vote of 30 to 6, and was approved on June 5.

On June 11 a letter was read before the Common Council, alleging that the use of alum as a coagulant was an infringement on patents held by the New York Filter Co. The letter stated that litigation on the subject was pending, and in case the allegation of an infringement should be held in a decision expected very soon, the New York Filter Co. would take legal steps to prevent the construction of a Morison-Jewell plant by the city. The decision was rendered in favor of the New York Filter Co. in a few days. While it was in some respects a barren victory, merely requiring, in the opinion of the other mechanical filter companies, the introduction of a settling tank or some device to prevent the direct application of the coagulant to the water as it enters the filters, yet it was sufficient to turn the tide against the proposed contract.

The friends of filter beds took advantage of the situation, and within two weeks of the adoption of the resolution for mechanical filters another order was before the City Council providing instead for sand filter beds of like capacity. Meanwhile Mr. Shedd had prepared the necessary plans for such beds, and an offer had been made by a firm of local contractors to carry them out for $200,000. A commission of the City Council was appointed to investigate filter beds, and the Commissioner of Public Works was directed to await further instructions before contracting for filters. The Morison-Jewell Filtration Co. on July 6 addressed a letter to the Commissioner expressing surprise at this order and insisting that it had already closed a contract with the city. The City Solicitor reported to the contrary, and nothing further came of the claim.

In the latter part of August the filter bed committee agreed to report for adoption by the City Council a resolution instructing the Commissioner of Public Works

> to build by contract, or otherwise, a suitable system of gravity filters . . . capable of filtering 15,000,000 gallons per day, in accordance with plans and specifications of the City Engineer.

The expenditure of $200,000 was authorized by the proposed resolution, and the previous orders for mechanical filters would have been rescinded, had this one passed. Later the resolution was declared passed in the Board of Aldermen by a vote of 4 to 1, the chairman ruling a quorum present, but not voting. When the scheme came up in the Common Council it was met with a proposition from a local firm of artesian well contractors, who offered to develop a supply of 15,000,000 gallons a day for $90,000. The filter bed proposition was laid over pending a report from Mr. Shedd on this scheme. Mr. Shedd reported on Sept. 10, and, of course, against the proposition. About the same time the New York Filter Co. addressed a communication to the Commissioner of Public Works, belittling sand filtration and offering to put in its own system, it is stated, for $180,000.

Our information and patience fail at this point, so the matter cannot be traced further, except to state that Providence still drinks unfiltered water, but the City Council has so far revived the filtration scheme as to make a resolution appropriating money for a filtration plant special order for April 27.

The publication of Mr. Weston's report was held in abeyance during the summer of 1894. On Sept. 10 the Board of Aldermen voted to print it, but the Common Council hung up the resolution from that time until Dec. 17, when by a vote of 23 to 5 it was killed.

The Weston Experiments.

Going back now to the records of the experiments, Mr. Weston states in his report that the preparations for these were begun in February, 1893, and that the experimental work was started March 27. No results are given in the report for the New York filter, not is it mentioned by name, the only allusion to it being as follows:

> Another experimental mechanical filter was also set up, at the expense of the owners of the same, and run for several months, but as the results obtained with this filter were not satisfactory, it will not again be mentioned in this report.

The two so-called natural sand filters were only 30 ins. in diameter, and had as filtering material only 2 ft. of sand and gravel, resting on a brick floor, with 1-16-in. spaces between the brick, the latter being supported by brick on edge, which in turn were placed on a solid cement bottom. The filtering material consisted of 20 ins. of fine sand, 1 in. of coarse sand and 3 ins. of pea gravel, the latter being at the bottom.

The Morison-Jewell filter was also 30 ins. in diameter, and had a height of 14 ft. It was provided with a revolving rake or agitator for loosening up the sand during the washing process. The current was reversed in washing. The filtering material was quartz, 34 ins. deep. The upper 2 ft. had an effective size of 0.59 mm. (0.023 ins.), and a uniformity coefficient* of 1½. The lower 10 ins. was of much coarser material.

The experiments were conducted almost wholly for bacterial efficiency, but attention was also given to the removal of color. Until the middle of October, or for 6½ of the 10 months of the experiments, all the bacterial counts, except those for five days, were made after from 42 to 62 hours cultivation. For the remainder of the period the counts were kept up as long as the growths continued, or for from 67 to 236 hours, and in addition a change was made from 15 to 10% gelatin.

*Dr. Gardner T. Swarts, Secretary, 48 Weybosset, St., Providence, R. I.

*The effective size is the diameter of the sand at the point below which 10% of the material by weight is of less diameter. The uniformity coefficient is the ratio between this diameter and that at the 60% point, on the same basis.

the latter being the usual nutrient media for water bacteria, Mr. Weston states.

Owing to this change in methods Mr. Weston discards all the results from mechanical filtration which he had obtained prior to Oct. 17, except the few counts named. Or, more properly, he merely records them, but ignores them in his study of the results obtained. He makes no comment on the work of the so-called natural filters, giving as his reason the "very limited time" available for preparing the report. The log for these filters is given, but it is of little value, owing to the design of the filters, the way in which they were operated and the fact that very exhaustive and careful experiments with sand filtration at Lawrence, by the Massachusetts Board of Health, have given us much more reliable data. The filtering material was only 2 ft. deep; it was taken out and repacked, or else replaced with more of different size a number of times; the material was sometimes disturbed by washing with a hose from below; and there were violent and frequent fluctuations in the rate of filtration. All these conditions were against the best results, and, as already stated, Mr. Weston makes no use of his data on sand filters when he wishes to compare the work of the Morison-Jewell filter with sand filtration. The sand filters were permanently shut down on Oct. 5.

Like Mr. Weston, we shall quickly pass by the sand filters. They gave as good results as could be expected under the circumstances, and emphasize conclusions already known regarding "how not to do it."

As has been stated, Mr. Weston makes no use of practically the whole of his work from March 27 to Oct. 17, that is, in drawing his final conclusions as to bacterial efficiency. It is not to be supposed that this work was valueless, as during it much was doubtless learned regarding methods and possibilities. Before taking up his discussion of results during the remainder of the time, it will be advisable to describe the methods employed in operating the Morison-Jewell filter and gaging the results obtained.

In washing the filters the current was reversed and the sand agitator kept in motion until the overflow water ran clear. The standard rate of filtration was 128,000,000 gallons per hour per day. The coagulant employed was basic sulphate of alumina, this having been decided on after trying chloride of alumina, carbonate and also bicarbonate of soda, caustic soda and chloride of iron. The soda salts were used in connection with the sulphate of alumina. The best results were obtained with the latter alone, as was to be expected.

Mr. Weston defines the "theory of mechanical filtration," when basic sulphate of alumina is employed, as follows:

> The alumina causes an artificial precipitation. A portion of the alumina is decomposed, forming sulphates of other bases and a flocculent precipitate of aluminic hydrate. A portion of it also combines directly with the organic matter present in the water, coagulating the same and thus helping to increase the precipitation. A sufficient quantity of the precipitate having been deposited on the top of the sand or quartz-bed of the filter and plugged into the interstices of the upper layer of sand or quartz grains, the filter is ready for service.

Obviously, if this theory be true, the filter will not do good work until the film of hydrate has formed on the surface of the filtering material. When the alumina was dropped into the filter Mr. Weston found that from one to three hours was required for that purpose. After experimenting he found that this time could be reduced by admitting a pint of coagulant, containing 911 grains of alumina, into the filter during the first six minutes or less after starting the filter. This amount was based upon the standard rate of filtration, 128,000,000 gallons per acre per day, and was in addition to the regular dose of alumina, which was introduced at the same time from another receptacle. By this means good results could be obtained in a half hour or less after starting the filter.

The coagulant was prepared by dissolving 1 part of alumina in 7 parts of water, each by weight. The heavy dosing at the start, denominated "free flow" by Mr. Weston, was done from a tin can and faucet. The regular dose was admitted from an earthen jar through a faucet and glass dropper. The drops were counted every half hour day and night, and the faucet regulated when necessary, a graduated measuring glass being used when required. The composition of the alumina was as follows:

	Per cent.	½ grain contains in grains.
Insoluble residue	0.52	0.0026
Alumina (AL_2O_3)	15.78	0.0789
Sulphur trioxide (SO_3)	36.79	0.1840
Water (by difference)	46.91	0.2345
Total	100.00	0.5000

One of the arguments often urged against mechanical filtration is that the chemicals used as coagulants may be harmful when taken in drinking water, especially when alumina in any form is employed. Mr. Weston spared no pains to ascertain whether any of the alum appeared in the filtrate. Careful experiments showed that by means of the logwood and acetic acid test 1 part of sulphate of alumina could be detected in 1,000,000 parts of distilled water, which is equivalent to 1 part of alumina proper (Al_2O_3) in 6,000,000 parts of water or 0.01 grains per gallon. This test being applied to the filtered water indicated the presence of alum in solution nearly every time. After consulting numerous chemists it was found that the tint was not due to the alum in solution, but to a small quantity of finely-divided aluminum hydrate in suspension. In making this test great care must be taken to have the logwood decoction fresh, and to act quickly. The acetic acid and logwood should be added to distilled water at the same time as to the filtered. If it is desired to filter out the suspended hydrate and then test for aluminum care must be taken to secure filter paper free from traces of aluminum salts. Mr. Weston was aided in these investigations by Dr. T. M. Drown, Mrs. Ellen H. Richards and Dr. S. C. Hooker, the latter making the suggestion that solved the difficulty.

When the experiments were begun it was understood that the bacteriological work would be under the charge of Dr. C. V. Chapin, Superintendent of Health. Early in September Dr. Chapin asked Mr. Weston for suggestions, and, after investigating the subject and consulting with Prof. H. C. Ernst, of the Harvard Medical School, Mr. Weston concluded that the cultivations should be continued until end growths, and that 10 instead of 15% gelatin should be employed as the nutrient media. This change was adopted for all work done during the period under discussion, or from Oct. 6, 1893, to the end.

A drawback to continuing the bacterial counts until end growths were reached was the liquefying of the gelatine before that time, this being the case in many instances. So far as we can judge from Mr. Weston's statements the variation in results between the counts at 42 to 62 hours and end growths, would not be worth the extra trouble in actual practice, being only a fraction of 1%. Regarding the two kinds of culture media there is, of course, no reason why the right one should not be used. The difference in results between the two, however, was not great, according to Mr. Weston.

From March 27 to Dec. 10, 1893, the work in the bacteriological laboratory was done by Dr. G. T. Swarts, with the exception of several short periods, when it was done by Dr. C. V. Chapin. From Dec. 11, 1893, to Jan. 31, 1894, Dr. M. T. Richardson conducted the work, and the counts necessary to close the investigation were made by Mr. Weston.

The bacterial results obtained from Oct. 6 to Jan. 30 are given in a series of 18 tables. Two other tables present a few chemical results and a large number of color observations, distributed over the period covered by the experiments.

Generally only one sample of applied water was collected each day, but from one to ten samples of filtered water were taken. The filtered water was taken at intervals during the first 30 minutes after starting the filters; at the same time as the applied water was taken, generally from 12 m. to 1 p. m., always one hour or more after water began to flow from the filter; and at other intervals during the day. End growths, growths at about 90 hours, the usual period for such work, and all growths of 85 hours or more that failed to reach end growths are appropriately presented in different tables. Unfiltered river water was used in washing the filter, except on six days in November, when filtered water was used. A number of tables are presented to show in detail how often the results were below the average.

Making allowances for possible errors, due to the bacteriological methods employed prior to Oct. 6, Mr. Weston assumes that from April 5 to Nov. 11, 1893, the Morison-Jewell mechanical filter removed about 99% of the applied bacteria. From Nov. 23, 1893, to Jan. 8, 1894, bacillus prodigiousus was added to the applied water, and an average of 96% of these were removed. From Jan. 9 to 23 the ordinary course was pursued and 92.8% of the applied bacteria were removed. On Dec. 7 and 11 the filter bed was steamed and boiled without improving the bacterial results. Before completing the experiments in January the filter bed was washed with a solution of 1 part of caustic soda to 24 parts of water, to remove the foreign matter with which the quartz grains had become covered. It was thought that ordinary water bacteria were feeding and developing on this matter, thus giving rise to abnormal results. This washing was done in the ordinary manner of washing the bed and produced good results. The quartz was cleaned and the bacterial efficiency was increased from an average of 92.8% during the period from Jan. 9 to 23, to 98.8% for the balance of the month.

During the period of inefficient working, or from Nov. 23 to Jan. 23, the amount of suspended matter in the water was small. The best work prior to Nov. 23 was done when more suspended matter was present. From this Mr. Weston argues that a certain amount of suspended matter was beneficial, and that if there had been more after Jan. 23 the efficiency would have been higher than 98.8%. The value of the suspended matter would be in forming a coating on the surface of the filters.

Mr. Weston's reason for basing his final conclusions from a year's work on the results during 33 days, aside from those already given relating to changes in culture media and lengths of growth, are expressed as follows:

> The average efficiency of the filter for removing water bacteria during the entire time it was running, from Oct. 17 to Jan. 30, inclusive, as may be seen from table No. 9, was about 95.2%. I do not consider 95.2% a fair average, however, as undoubtedly between Nov. 23 and Jan. 23 the quartz grains of the filter-bed were, more or less, covered with growths of bacteria, and it is quite possible that bacteria were propagating in the other parts of the filter.
>
> I have, therefore, based my bacteriological conclusions, which are to follow, upon the work that was done from Oct. 17 to Nov. 11, when the filter, from a bacteriological standpoint, appeared to be in its normal condition, and from Jan. 24 to 30, after the bed had been washed with the solution of caustic soda and water, and again brought to its normal condition.

When Mr. Weston compares his results with those obtained at the Lawrence Experiment Station, he finds that certain abnormal results there were omitted from the averages on practically the same grounds as he urges above in connection with his own work—that is, abnormal growths in the underdrains of the Lawrence filters. Mr. Weston thereupon recomputes the Lawrence averages to include these abnormal results. He justifies this failure to allow the same latitude in the Lawrence work as he assumes in his own in this manner: If abnormal results were obtained in a well-constructed mechanical filter, probably it would not be necessary to theorize as to the cause,

> as the filters of the plant could be thoroughly cleansed by washing them with a solution of caustic soda and water in a short time and at a very slight expense in proportion to the total cost of operating the plant.

On the other hand, he urges that if abnormal results occurred in sand filters, apparently due to growths in the outlet pipes and underdrains,

> it would be a very difficult matter to free the filters of the abnormal growths of bacteria, even if it could be done by artificial means, but by the expenditure of very considerable amount of time and money, on account of the large area of the filter-beds, which would be required.

Mr. Weston then goes on to say that if the excessive number of bacteria were harmless it would not matter, except that the stability of the filter beds might be questioned, but if just at this time there should be a few cases of typhoid fever in the area from which the unfiltered supply was drawn, it would be a matter of grave concern.

Whether this course of reasoning is sufficient to justify the inclusion of abnormal results for sand and their exclusion for mechanical filtration, is at least open to serious question. As a matter of fact, the Lawrence results used by Mr.

Weston, as he points out, extended over a long period and were derived from many filters, while his results are based on one filter and 33 days time, this period being selected, as has been fully explained, from the work of nearly a year.

Since the comparisons with the Lawrence work have been mentioned, the subject may as well be completed here. It was stated above that for the 33 days selected by Mr. Weston, the average results were a removal of 98.8% of the bacteria in the applied water. By a little different combination of his figures he gives 98.6% as the actual removal, determined from all the analyses during the period. The Lawrence results with sand filtration show slightly greater removal, a total of 99.5%, or an excess* of 0.9%. After presenting these figures Mr. Weston states:

I do not consider that the efficiency of a filter should be entirely based upon the average results obtained, although this is generally the standard upon which the efficiency is based, but the worst results obtained should be duly considered.

He then shows how a high average may be presented, even with a number of the individual results very poor, and goes on to compare the number of times the individual percentages of removal fell below the average with sand filtration at Lawrence and mechanical filtration at Providence. Here again the figures are in favor of the sand filters, 87% of the results being below the average, against 16.7% for the mechanical filters, but the range of per cents. below the average is from 1 to 80 for the sand, against only 1 to 3% for the mechanical filters. These figures for the mechanical figures are for samples taken one hour or more after starting the filters. For samples taken 30 minutes or less after starting the filters 23.1% of the total results are below the average, this average, by the way, being 96.1% removal, showing the advantage of letting the water waste for a half hour after starting the mechanical filter.

The length which this abstract has reached is sufficient evidence that we cannot go into all the details from which the above figures are drawn. An examination of the table in which the Lawrence figures for sand filtration are presented shows that the number of times when the percentages of removal went far below the average was few, while the total number of examinations included was many times greater here than for the mechanical filters. Moreover, as pointed out above, Mr. Weston has excluded his own abnormal results, but included those obtained at Lawrence. A still further point is that not only do the Lawrence figures cover many results from many filters, but some of those filters were constructed not to obtain perfect results, but to ascertain what a given kind or combination of materials would accomplish. The Providence figures were obtained with one filter, which was being operated for high efficiency rather than in a general search for data regarding filtration.

Only three chemical examinations were made to determine the ammonias. The average of these showed a reduction of 70% of albuminoid and 91% of free ammonia by the Morison-Jewell filter. From figures on pp. 469 to 489 of the Massachusetts State Board of Health for 1892 Mr. Weston computes that from June to November of that year 58% of the albuminoid and 88% of the free ammonia was removed by sand filtration at the Lawrence Experiment Station by the experimental filters from which he drew his bacterial conclusions given above. The total residue in the Providence water was so slight as to be increased by the mechanical filtration process, through the addition of the coagulant.

The effect of filtration upon color from June 28 to Oct. 26 was a reduction of 81%; from Oct. 26 to Jan. 30, 78% by day and 66% by night. The color was determined by standard samples ranging from 1 to 10, prepared by Prof. J. H. Appleton, of Brown University. The difference between the day and night samples may have been due to the fact that the latter stood some time before being examined, Mr. Weston states. The results at the Lawrence Experiment Station for 1892, the report states, were 60% removal after 100,000,000 gallons had been filtered, and 45% after filtering 400,000,000 gallons. In estimating the cost of operating mechanical filters Mr. Weston allows for washing with caustic soda twice a year. In an appendix to the report it is stated that he has since found that soda ash and steam may be substituted for the caustic soda at a much reduced cost.

In summing up the results of the investigation Mr. Weston states that the best coagulant for Pawtuxet River water is basic sulphate of alumina. His estimates are based on using 0.6 grains per gallon of this for an average run of 16 h. 43 min., including the heavy dosing at the start. This is equivalent to 0.5 grains per gallon while the filter is in effective service.

Mr. Weston thinks that none of the basic sulphate of alumina, in its original state, was present in the filtered water after the latter had been flowing 21 minutes. Wasting the filtered water during the first 30 minutes after washing and starting the filter anew would, of course, exclude the coagulant from the filtrate.

The rate of filtration recommended for Providence was 100,000,000 gallons per acre per day.

On the subject of washing the report states:

Our experiments have shown, I think, that the filter-bed could be very thoroughly washed by the aid of the mechanical rake or agitator.

The average time required for washing the filter-bed was about eleven minutes.

The quantity of water required to wash the filter-bed, based on a run equivalent to a rise of 4 ft. of water in the filter after the full capacity had been reached, averaged about 4.9% of the quantity of water that was filtered during each run.

The quantity of water which it would be necessary to run to waste after washing the filter-bed was based on the water running to waste 30 minutes, for the reason that I have previously mentioned, and averaged about 2.9% of the quantity of water that was filtered during each run.

The frequency of washing was determined by the rise of water in the filter tank due to the increased resistance as the filter clogs up. The water stood at about 6 ins. on starting the filter, and the standard was to begin washing when it reached 4 ft. With 0.5 grains of alumina and the heavy dose, or "free flow," at the start, the average run at 128,000,000 gallons per acre per day was, after Oct. 17, 1893, 16 h. 43 min., ranging from 13 h. 22 min. to 19 h. 44 min. From April 26, 1893, to Jan. 30, 1894, the average run was 16 h. 53 min., ranging from 6 h. 27 min. to 26 h. 53 min. With 0.75 grains of alumina per gallon the average run was 15 h. 2 min., and the range from 13 h. 28 min. to 17 h. 37 min., this being for the period from Oct. 17 to Jan. 30.

The condition of the river water was quite varied, but the water had some opportunity to settle before reaching the filter. A number of examinations showed 40% less bacteria in the water actually applied to the filters than in water directly from the river. Regarding the effect of these variations on washing, the report says:

The length of any of the runs of the filter did not materially change on account of the different conditions of the water in the river, with the exception that, occasionally during the summer months, after heavy rains, the length of time was reduced about one-half.

The working head of the filter at shutting down for washing ranged from 3.5 to 6 ft., with as good results for the higher as the lower head.

Of the bacteria in the applied water it is estimated that about 73% were intercepted at the surface and in the upper ¾ in. of the filtering material; 24% in the next 5¼ ins. and that the remaining 3% went down into the lower part of the filter, or through it into the filtrate, the average number passes through being about 1%.

The average loss of head caused by the resistance of the filtering material, screens and filter outlet pipe was 2.44 ft. when filtration was going on at the rate of 128,000,000 gallons per acre per day.

In concluding this part of his report Mr. Weston states:

From a mechanical standpoint, the working of the experimental Morison mechanical filter, throughout the experiments, was very satisfactory.

I have estimated $5.69 as the cost per 1,000,000 gallons, of operating a Morison mechanical filter plant (having an effective capacity of 15,000,000 gallons per 24 hours), throughout the year.

This figure for cost of operation Mr. Weston reduces in his appendix to $4.52 per 1,000,000. This he does by substituting soda ash and steam in place of caustic soda for washing the filtering medium twice a year, and by substituting unfiltered for filtered water for washing the filters.

A number of estimates are subjoined to the appendix at the request of the Secretary of the Rhode Island State Board of Health, giving the cost of constructing mechanical and sand filtration plants after four different plans each, and the cost of filtration per 1,000,000 gallons for each plan, including 4% interest, an allowance for repairs and deterioration, with an alternative figure of 2% sinking fund instead of deterioration. Each of the estimates is for a plant with a daily capacity of 15,000,000 gallons. For the mechanical filters basic sulphate of alumina, costing 2 cts. per lb., is included to the average amount of 0.6 grains per gallon of water filtered. The estimates for mechanical filters also include brick filter house with iron roof and concrete floor, smokestack, filter connections, pumping plant in duplicate, electric lighting and signaling apparatus and all necessary accessories for a first-class plant. It has also been assumed that the site for the building would be already graded and such as to afford good natural foundations. Likewise it has been assumed that in constructing filter beds the excavated material would be suitable for embankments and that no special difficulties would be encountered; also that sand could be found in the immediate vicinity of the beds, suitable for use without washing or screening.

The cost of land has not been included in any of the estimates, and obviously this might be an important factor in some cases, as so much more would be required for filter beds than for mechanical filters.

A summary of the various estimates is given below, preceded by explanatory remarks, as follows:

Estimate No. 1 is for 60 steel filters, working at 100,000,000 gallons per acre per day when all are in operation, or 106,000,000 when a gang of three are being washed. This is the plant, it appears, on which estimates for Providence were based. The lower rate of 100,000,000 gallons, instead of the 128,000,000 standard in the experiments, was taken so the filters would not need so frequent washing as once in 16 h. 43 min.

Estimate No. 2 is for cypress instead of steel tanks. Estimate No. 3 is for 51 steel filter tanks, the filters working at 119,000,000 gallons an acre when all are in operation and 126,000,000 gallons when three are being washed. Estimate No. 4 is for cypress instead of steel tanks, the other conditions being the same as for No. 3.

The estimate for the first of the sand filter plants, No. 5, is based on the actual cost of constructing and operating the 2½-acre filter bed connected with the city water-works of Lawrence, Mass., with an estimate (made by Mr. Allen Hazen) for covering such beds with a masonry roof. The rate of filtration is 2,000,000 gallons an acre. Estimate No. 6 is on the same basis as No. 5, except that it assumes a wood covering for the filters, based on an estimate for covering the Lawrence filters, submitted to the Water Board of that city. In both these estimates the rate of filtration with one-fifth the area out of service for cleaning is 2,500,000 gallons an acre. Estimate No. 7 is the same as No. 6, except that the regular rate of filtration is increased to 2,500,000 gallons, or 3,125,000 gallons when part of the area is being cleaned. Estimate No. 8 is on figures made by Mr. Weston for ten beds, not covered, each having an area of 0.94 acre, to work at a rate never exceeding 2,000,000 gallons an acre, and to have a depth of about 4 ft. of water on their surface. Eight of these beds would be kept in operation and two in reserve for cleaning or other purposes.

Summary of Estimates for 15,000,000-Gallon Mechanical and Sand Filtration Plants.

	First cost.	Fixed charges.	Cost per 1,000,000 gallons filtered.— Opera-tion.	Total.	Revised total.*
Mechanical Filtration.					
No. 1. 60 steel filters.	$245,172	$3.15	$4.52	$7.67	$7.48
No. 2. 60 cypress "	229,452	3.34	4.52	7.86	7.28
No. 3. 51 steel "	212,404	2.73	4.52	7.25	7.08
No. 4. 51 cypress "	198,934	2.89	4.52	7.41	6.91
Sand Filtration.					
No. 5. Filter beds, masonry covered	525,000	4.47	4.39	8.86	10.30
No. 6. Filter beds, wood covered	328,598	3.75	4.39	8.14	8.05
No. 7. Filter beds, wood covered	262,878	3.00	4.39	7.39	7.32
No. 8. Filter beds, not covered	291,220	2.48	4.39	6.87	7.67

*The revised total includes the same figures as the previous one, with the exception that a 2% sinking fund is allowed in place of deterioration.

*If the common method of averaging average per cents. were followed, Mr. Weston shows, then the Lawrence results would have been 98.2% or 0.04% less than those at Providence.

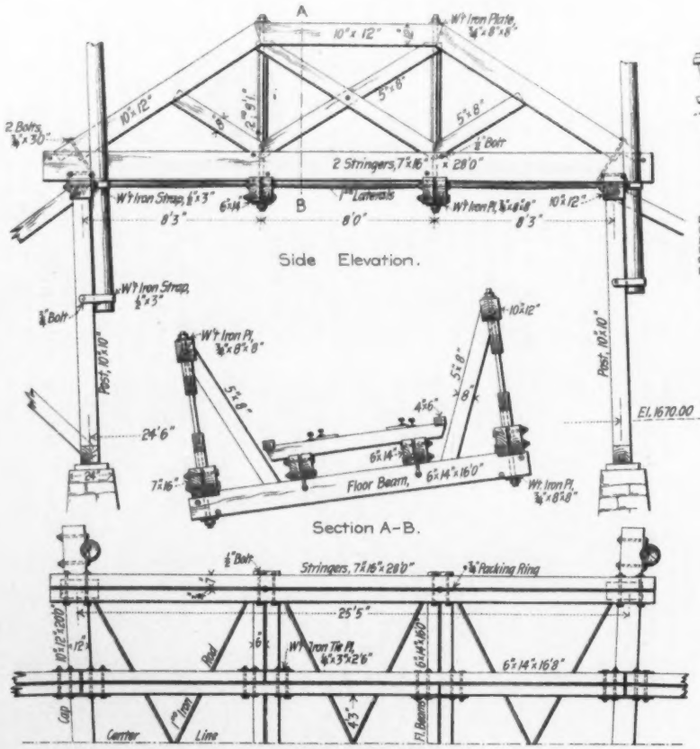


FIG. 2. DETAILS OF WOODEN TRUSS SPAN OVER STREET.

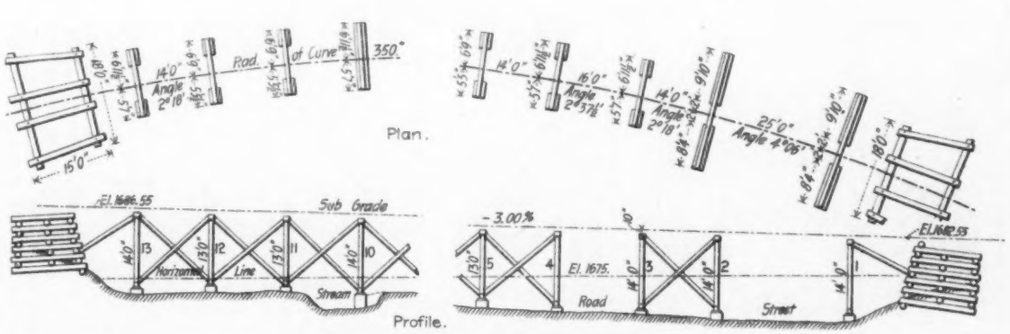


FIG. 1. GENERAL PLAN AND PROFILE.

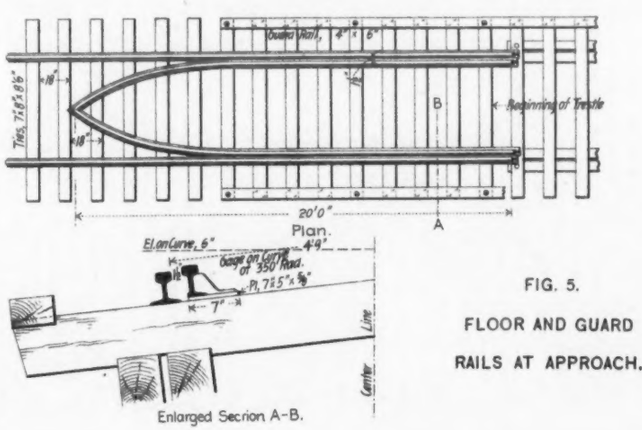


FIG. 5.

FLOOR AND GUARD

RAILS AT APPROACH.

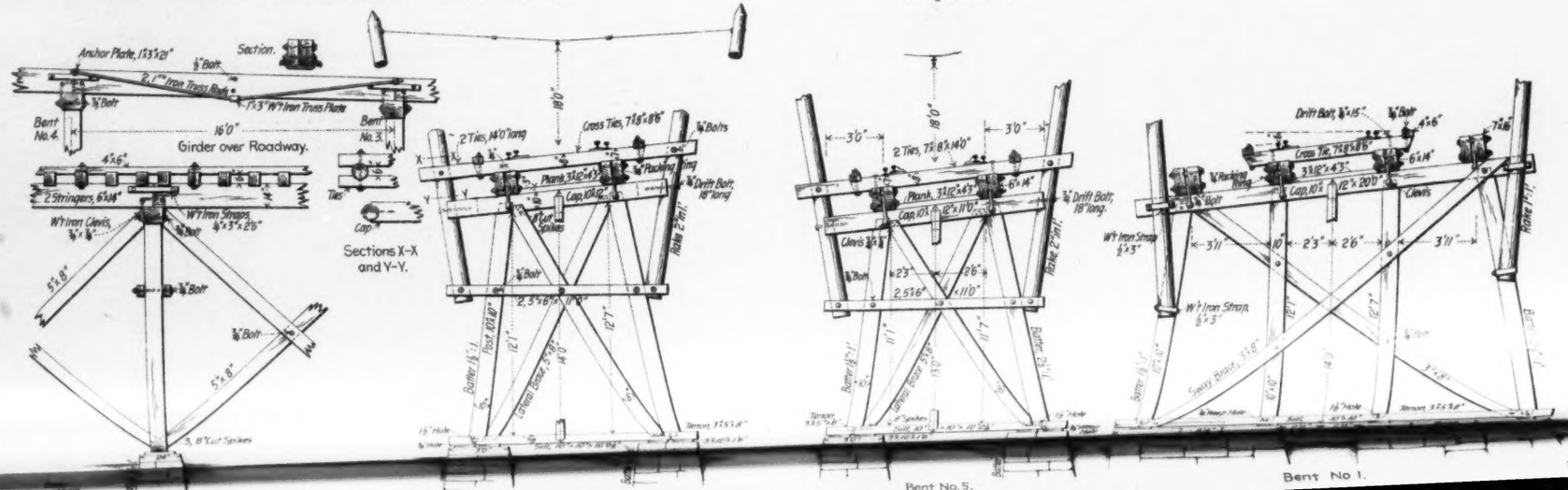


FIG. 4. DETAILS OF BENTS AND GIRDER OVER ROAD.

FIG. 3. DETAILS OF BENTS 1 AND 5.

TRESTLE FOR SINGLE TRACK ELECTRIC RAILWAY.

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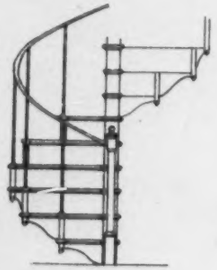

Fig. 1.

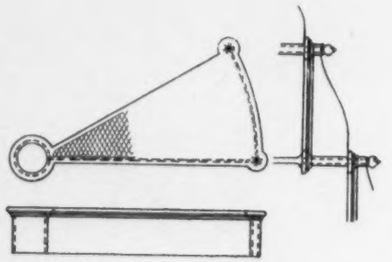

Fig. 2.

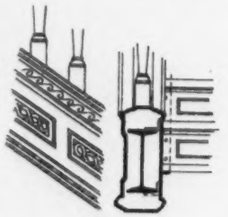

Fig. 3.

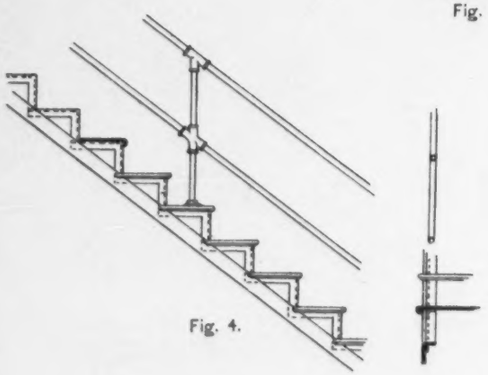

Fig. 4.

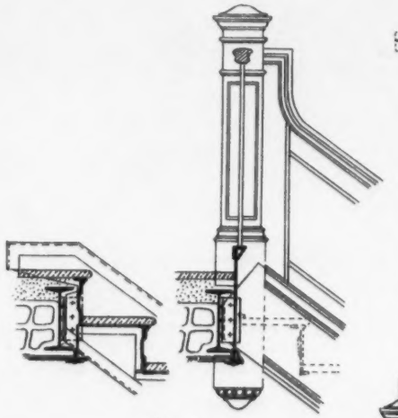

Fig. 5.

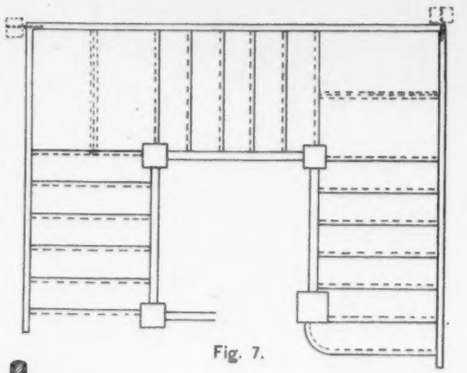

Fig. 7.

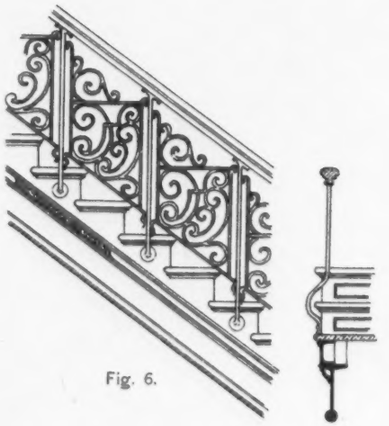

Fig. 6.

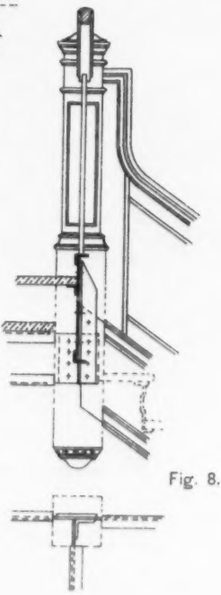

Fig. 8.

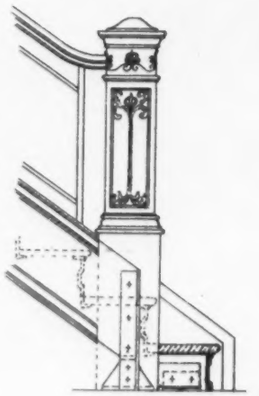

Fig. 9.

TYPICAL STRUCTURAL DETAILS IN METAL STAIR WORK.

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